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New system of signalling on the Belgian State Railways,

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Figs. 1 to 29, pp. 420 to 441.

INTRODUCTION.

Mr. L. Weissenbruch, engineer, administrator of the Belgian State Railways, gave the last years of his life to the study and perfecting of railway signalling, which was being dealt with on the Belgian lines before the war, adapting the principle, used in America, of a three-position signal arm.

Immediately after the armistice the Administration of the Belgian State Railways adopted, at his suggestion, the signal giving three indications in the place of the old signalling system destroyed by the enemy.

The Belgian signalling system in use previous to 1914 had already been the subject of an article published in the *Bulletin of the Railway Congress* of October 1909.

This new system is already at work on the principal Belgian lines, more especially on the Brussels-Antwerp, Brussels-Ghent-Ostend, Brussels-Namur-Arlon, Brussels-Liége-Herbesthal and Brussels-Tournai lines, and has proved its value from the point of view of simplicity and the clear indication it gives to drivers. It is at the present time also being installed on the Brussels-Mons and Brussels-Charleroi-Namur lines.

We cannot better honour the memory of Mr. Weissenbruch than by publishing this article, which has for its object the justification and description of the principle of this method of signalling and to show how it is applied on our railways.

In order to do this we have made use of Mr. Weissenbruch's scattered notes which he was putting in order when death intervened and put an end to the work which he had so conscientiously applied himself.

We will describe in a second article the apparatus used to work the signal arms in the different cases where it is applied.

* * *

CHAPTER I.

General remarks.

Several years before the war the Belgian State Railways had adopted the English system of railway signalling.

This system is universally known, and those of our readers who wish to become better acquainted with the details can find them clearly explained in English in the recent book written by Mr. L. P. Lewis, and in French in the remarkable article by Mr. Ed. Sauvage, published in the *Annales des Mines* in France.

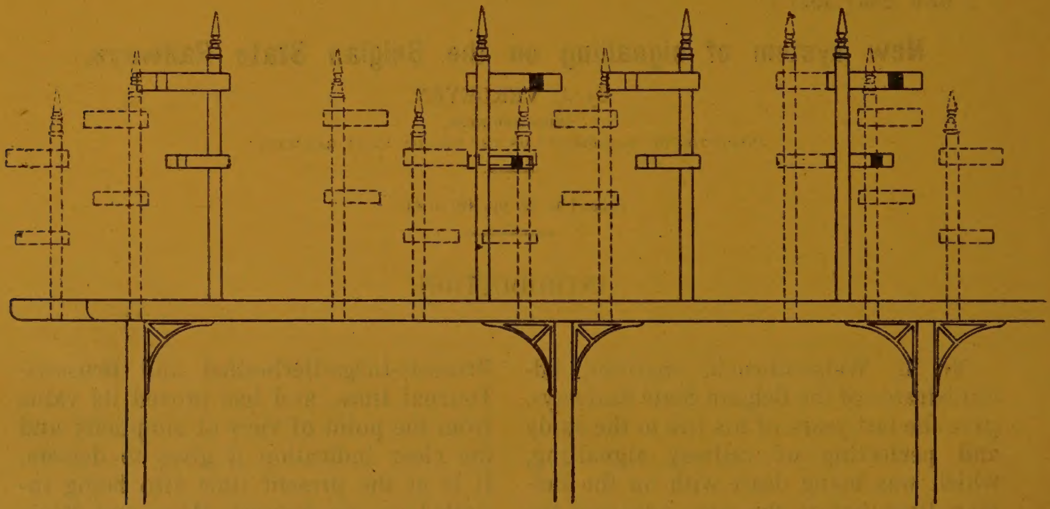


Fig. 1*a*.

Several improvements in detail had been added to this system, most of which had been recommended, if not put into actual practice, on English lines, such as, substituting an orange coloured light for a red one on the distant signal, which may be passed at danger; also raising the signal arm instead of lowering it, and the addition of route indicators (figures or letters) working with signal arms at junctions at all places where trains were liable to pass these signals at reduced speed.

During their occupation of the country, the Germans would not change their own system of signalling, and looking with disdain on the country's future, completely destroyed all Belgian signals, replacing them with a German system designed for lines carrying little traffic.

The whole of the signalling arrangements on the main lines having therefore to be reconstructed, the Belgian State Administration inquired if it were not possible to simplify the English system without interfering with the clearness of the indications given to drivers.

This simplification has already, even in England, been recognised as necessary

for junctions and large stations, where the use of signal arms placed horizontally necessitated fixing a number of posts and brackets or complicated gantries.

Figure 1, taken from a paper given by Mr. W. C. Acfield and published in the proceedings of the « Institution of Electrical Engineers » of London, shows how a group of forty-two signal arms was reduced to sixteen on the Midland Railway by the use of route indicators.

It was necessary also to abolish another important source of complication resulting from the distant signal being often placed under the rear home signal [1] due to the sections in which the trains were running becoming shorter and shorter.

The two arms thus arranged work in close harmony one with the other, by

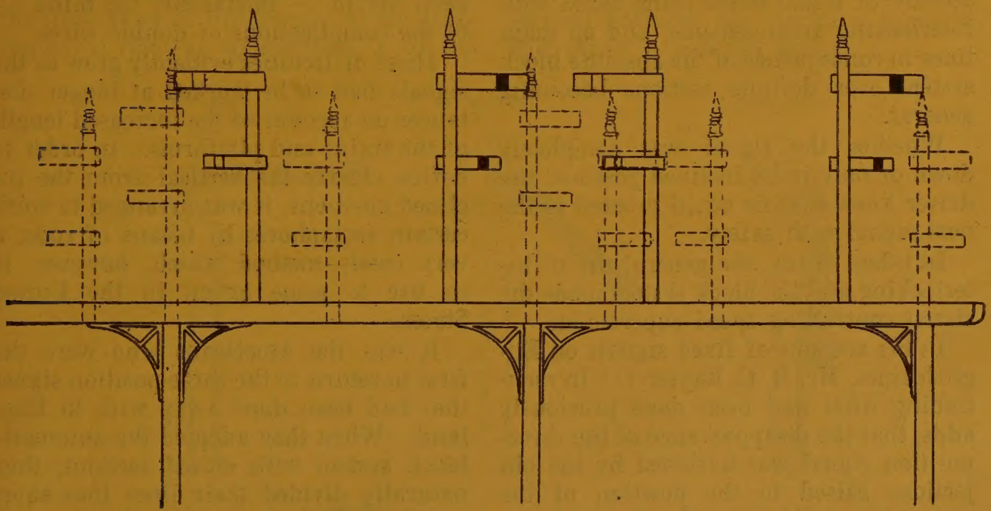


Fig. 1*b*.

means of a slot mechanism so that they may give as a whole only three indications :

Stop	Both arms horizontal ;
Road clear . . .	Both arms inclined ;
Stop at next signal.	Top arm inclined and bottom arm horizontal.

From this arrangement the idea naturally occurs to one to replace the combination of two arms by one arm which will indicate three positions, horizontal, vertical or inclined at 45°.

* * *

This shows how history constantly repeats itself.

When the disc signal was first replaced by the semaphore on English lines by C. H. Gregory at New Cross, this semaphore gave three indications :

1° Arm horizontal for a stop (danger);
2° Arm inclined downwards 45° for caution;

(1) According to the paper given by Mr. A. M. Thompson at the « Institution of Civil Engineers » in 1885, this arrangement of placing the distant signal under the stop signal in England goes back to 1880. Previously the rear home signal was slotted by the front one and served as a distant signal. The invention of the slot, that is to say the control of a signal by means of a second lever, must have taken place about 1862.

3° Arm vertical and out of sight inside the post for the maximum speed allowed on that section of the line (line clear).

This form of signal was still in use at intermediate stations on most of the English lines in 1874. It was done away with on account of two improvements which made it unnecessary to indicate slowing up or caution : at junctions, on account of signal boxes being fitted with interlocking arrangements, and on main lines in consequence of the absolute block system over definite sections becoming general.

Whether the signal was completely down or only in its inclined position, the driver knew that he could proceed to the next signal with safety.

In other words, the general use of interlocking and the block system made the signal controlling speed superfluous.

In his account of fixed signals on English lines, Mr. R. C. Rapier (1) in mentioning what had been done previously adds, that the disappearance of the three-position signal was hastened by the objections raised to the position of the arm when hidden inside the post, by those who favoured the use of positive signals.

Was it not also in order that the signal should always be completely visible whether for danger or line clear that the disc signal was abolished in favour of the semaphore?

There was certainly also another reason which tended to do away with the third position arising from the difficulties encountered in order to regulate exactly the three successive positions of an arm when it is worked by means of a single wire, a system which has always been in vogue in England where signal engineers have been afraid — mistakenly we think — of the complications of double wires.

These difficulties evidently grew as the signals had to be worked at longer distances on account of the increased length of the trains and platforms. In order to define clearly the vertical from the inclined positions, it was arranged to work certain semaphores by means of rods, a very costly method which, however, is in use to some extent in the United States.

It was the Americans who were the first to return to the three-position signal that had been done away with in England. When they adopted the automatic block system with closed sections, they naturally divided their lines into short sections. At the beginning of each one it was necessary to repeat the signal ahead so that the trains should not have to slacken speed unnecessarily.

The placing of the distant signal under

Fig. 2.

the home signal then became a general rule on the first lines fitted with the automatic block system, as shown in figure 2.

It was simply with a view to economy that led the Americans to go back to the three-position signal, which with one arm only gave the three indications given previously by two, as shown in figure 3.

(1) *Institution of Civil Engineers*, 31 March 1874.

With this arrangement, instead of two lamps, only one is required giving a red light for stop, yellow for stop at the next signal and green for line clear.

Fig. 3.

The block signal working in three positions was first introduced, we believe, on the Pennsylvania Railroad, and is mentioned by this railway in its reply, for the lines West of Pittsburgh, to the questionnaire relating to question X of the London Congress (1895) as a very good innovation [1]. In the description it is insisted that the arm should be plainly visible and detached from the post in its vertical position, but figure 4, however, still shows it hanging down.

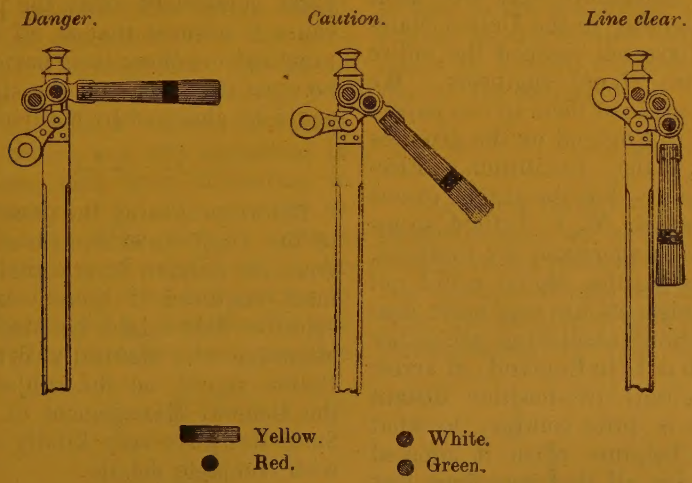


Fig. 4.

The block signal giving three indications with an upwards inclined arm became popular in America after the Autumn meeting in 1899 of the « American Railway Signalling Club », at which Mr. Frank Rhea, signal inspector of the Pennsylvania Railroad on the lines West of Pittsburgh, read a paper strongly recommending their use.

The raised position of the arm, which is not hidden behind the post, but stands out well away from it, completely destroys any objection that was formerly brought against it in England as not being a positive signal.

It is curious that the arrangement adopted in America for using the three-position semaphore by which it has obtained its success is nothing else but an adaption of the well known semaphore of the Great Northern, already described in 1885 by Mr. A. M. Thompson in his

[1] See the remarks by Mr. Theo. N. Ely, chief engineer for Tractive Power (*Bulletin du Congrès des chemins de fer*, June 1895, p. 2421).

paper on signals on the London and North Western (1).

In reality, the three-position signal only entered into practical use in automatic signalling in America, because the electric or electro pneumatic manipulation of it made it possible to regulate exactly the three positions and so avoid any doubtful signal.

* * *

The great advantages derived from the three-position signals, which took the place of the semaphore with two arms one above the other in the United States since 1900, have not escaped the notice of the English signal engineers. We find mention made of them in two papers recently read in England on the progress of signalling, at the « Institution of Electrical Engineers », but the author of one of these papers, Mr. W. C. Acfield, seems to think, if we understand his meaning, that the three-position signal could not be adopted unless its use was made general and without abolishing altogether the actual fish tail (in England) or arrow end (in Belgium) two-position distant signal. This is quite contrary to what happened in Belgium when it adopted this method, for all that was done was to substitute a three-position signal for the old arrangement

where this happened to be, and leaving everything else exactly as it was.

(1) « The signalling of the London & North Western Railway » (*Institution of Civil Engineers,* 5 May 1885).

Mr. C. M. Jacobs, author of the second paper read before the « Institution of Electrical Engineers », and to which we have referred, sees nothing but gain in the three-position signal, the multiple action of which he considers ideal, but states that its use « is only possible on condition it is worked electrically ».

This may be true in England where they have always refused to substitute the double for the single wire for working the signals. It will be seen in another article that the use of the double wire, which became general in Belgium about 1900, completely solves the problem, because it ensures that at all distances in practical use there is as perfect harmony between the lever and the signal arm as could be obtained by electrical means.

* * *

Before proposing the general adoption of the Anglo-American three-position signal, the Belgian State signalling department enquired if there was any other solution that might be preferable. Its attention was naturally drawn to the Italian signal, on the subject of which the General Management of the Italian State Railways very kindly supplied us with complete details.

In this system the two arms, fixed one above the other, have been simply placed together on the same axis, but neither has been done away with.

The economy obtained is really only due to the light, which is produced by means of one lamp only (fig. 5).

The Italian system raises an objection of principle, that is, the two arms forming the signal mutually cover each other in the two extreme positions of danger and line clear; the signal therefore is not absolutely *positive,* as all signalling given by means of a semaphore should be. To get over this objection in the type used

in upper Italy, the stop arm makes an angle of 60° with the horizontal when showing line clear, whilst the back signal arm makes only an angle of 45°.

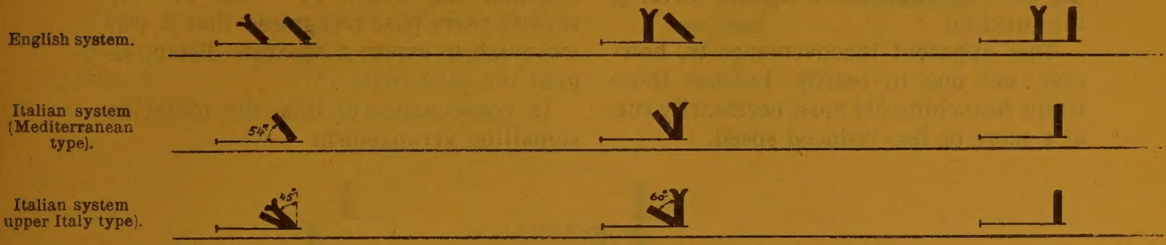


Fig. 5.

As it is, however, the Italian signal has a marked superiority over the two-armed English arrangement one above the other, as it is not so high and is less cumbersome. This is a great advantage in tunnels, which are very numerous in Italy. There, each arm continuing to work separately, it is not necessary as with the three-position arm to contend with the difficulty of exactly fixing the two positions of line clear and caution so that they shall never be mistaken for one another. It has therefore been possible to keep to the old method of working the signals by single wire without having to resort to a more improved one such as that of the double wire.

* * *

Proceeding further with our efforts for simplification, we conceived the idea of putting in the place of the bracket carrying multiple distant signals for a junction, one semaphore only fitted with one three-position arm (fig. 6).

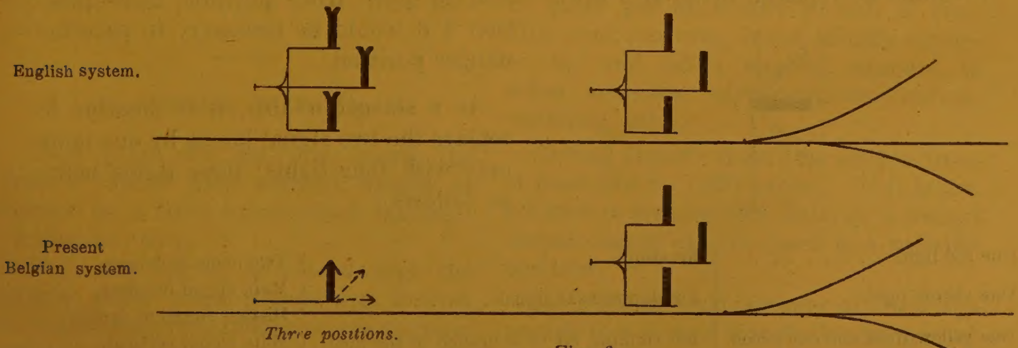


Fig. 6.

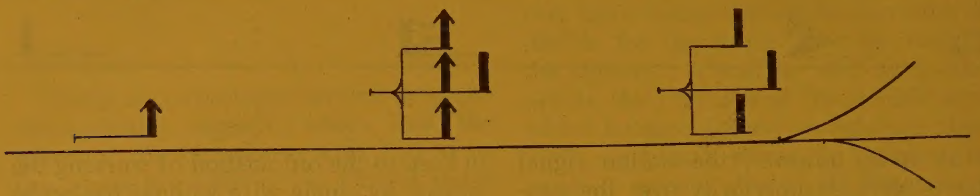
The three-position distant signal is no longer an identical reproduction of the junction signal, but is rather a signal for express trains. It informs the driver who is running straight ahead, that in its upright position the line is clear; a driver, however, who is taking the left direction for instance is not certain when

he sees the distant signal arm at 45° that it is not the right hand branch that is clear, for he can only be certain on seeing the bracketed home signals covering the junction.

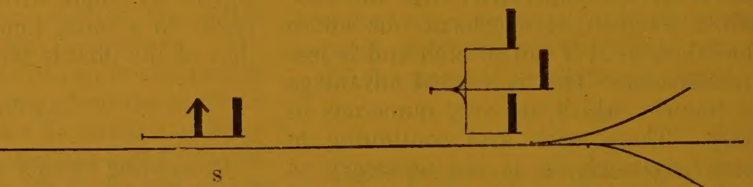
This apparent inconvenience is, however, not one in reality, because those trains branching off must necessarily run at a more or less reduced speed.

This simplification, moreover, fulfils a requirement which has made itself felt elsewhere than in Belgium. Even in England the Board of Trade has for several years past recognised that it was too much to expect a separate distant signal for each route (1).

In consequence of this, the following signalling arrangement



will be replaced by

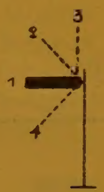


Distant signal arm indicating three positions.

Fig. 7.

The semaphore S only gives four indications.

It cannot be replaced by an arm working in four positions, because one of these positions must come below the horizontal, and to pass from position 2 to position 4 it would be necessary to pass the danger position.



As a set off to this, it is possible to replace the two signal lamps by one lamp only with four lights; these lights being as follows :

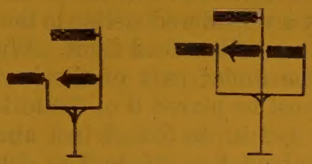
One red light	for stop.	Two arms at danger.
One yellow light.	for stop at next signal	Main signal inclined. Distant signal at danger.
One yellow light and one green light	for running on to a branch at the junction	Main signal vertical, Distant signal inclined.
One green light	for taking the main line at the junction	Two arms vertical.

(1) W. C. Acfield, 31 March 1915 (*Institution of Electrical Engineers*).

The result is that most of the bracket signals will be replaced by semaphores with two arms, one above the other.

Very few bracket signals of form *a* will remain and only exceptional cases of form *b*.

All kinds can be constructed of standard parts and fitted up beforehand.



a *b*

CHAPTER II.

Introduction of the three-position signal in conjunction with distant signals in the signalling system of the Belgian State Railways.

The introduction of the new method of signalling has caused no practical difficulty. Not only did the drivers easily become used to it, but even welcomed it as an improvement. It is only necessary to go over the lines on which it has been applied in order to understand how simple and clear are the indications given by it.

Later on we will describe the principles of the new system of signalling actually applied on the principal lines of the Belgian State.

§ 1. — **Position of the signals.**

Each point on the line which the drivers cannot pass without danger is marked by a fixed *signal which indicates an absolute stop.*

This stop signal is placed near the danger point when it concerns drivers of trains that are standing or are running very slowly (platform lines and subsidiary lines at stations, sidings, locomotive sheds, etc.).

When it concerns drivers of trains running on the main line, the danger signal is generally placed about 50 m. (55 yards) from the danger point, and its indications are repeated by a distant signal placed 800 m. (875 yards) behind it and which may be passed at danger. This distance can be reduced to 600 m. (655 yards) on an up gradient or increased to 1 000 m. (1 093 yards) on a descending gradient. The distance of 875 yards is used also for inclines not exceeding 1 in 200, beyond which it is increased or diminished by 22 yards per millimetre of fall or rise. This rule, however, is not strictly adhered to, and when applied, account is taken of other circumstances (curves, visibility, etc.).

Distant signals should be visible from at least 300 m. (328 yards). If it is not possible to arrange this distance, a second distant signal may be fixed in a suitable position.

In order to warn drivers of their approach to a distant signal, five horizontal white location boards or barrier markers are provided. These are placed obliquely to the centre line of the railway, each one being 5 m. (16 1/2 feet) long and spaced 50 m. (55 yards) apart. The width of the horizontal part must be at least 30 cm.

(11.8 inches). The boards are so placed that they are rendered visible to the driver by the locomotive head light. With this object the under part of the horizontal board must be placed 0 m. 70 to 1 m. 70 (2 ft. 3 1/2 in. to 5 ft. 7 in.) above the rail, or about 1 m. 20 to 2 m. 20 (3 ft. 11 1/4 in. to 7 ft. 2 5/8 in.) above formation level. The boards are numbered by means of black slanting lines 15 cm. (5 7/8 inches) wide formed with laths standing in relief on the white surface of the board. The nearest board to the signal carries one of these laths, consequently the first board encountered by the train is provided with five.

Unless it is not possible to do otherwise, the signals are placed on the left hand side of the line to which they refer.

If on account of local circumstances a signal cannot be placed on the left of the line, a suitable support in the form of a bracket or gantry may be used so as to bring the signal to the centre line of the road.

§ 2. — Shape and meaning of the signals.

A. *Ordinary arm.* — The arm of the home signal takes the form of an *elongated rectangle,* the front face of which is coloured red crossed with a white line (fig. 8*a*).

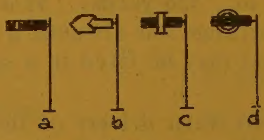


Fig. 8.

In large stations, some of the arms are fitted with a vertical bar painted black; these are called *terminal arms* (fig. 8*c*) because they are placed at the end of the road on which the trains can run.

When they refer exclusively to the entrance to a loop line, the ordinary arm is fitted with a ring painted *black* (fig. 8*d*).

The horizontal position of the arm of a stop or home signal (red light at night) indicates that a stop must be made; its inclined position (yellow light at night) indicates to proceed at caution, but gives a warning that the next signal is at danger. Its vertical position (green light at night) indicates line clear and that normal speed may be maintained.

B. *Back or distant arm.* — The distant signal arm is shaped with an arrow point at the end and its front face is coloured yellow with two transverse arrow shaped black marks (fig. 8*b*).

The horizontal position of a distant signal (yellow light) allows the train to proceed, but indicates that the next signal is at danger. Its inclined position (double lights, yellow and green) signifies attention and informs the driver that he will have to slow up at a certain point. If this indication is given at a junction, it means that a signal covering a branch is showing line clear. Its *vertical* position (green light) informs the driver to proceed at normal speed. At a junction this indicates that the home signal is off for the straight road.

C. *Stop discs.* — Use is sometimes made of red discs instead of semaphores to guard subsidiary lines or certain lines forming a group of goods lines.

When standing *perpendicular* to the road it means stop (red light), but if *parallel* to it the line is clear (green light).

D. *Shunting.* — Shunting or siding operations are governed by means of signal arms of smaller dimensions and able to occupy three positions in relation to the post on which they are fixed, *horizontal, inclined to 45°* and *vertical.*

The front face of these arms is coloured *red* and the back face *white*.

When shunting or loop line operations are being carried out on main lines, a special shunting arm is fitted to the semaphore post below the ordinary arm.

In this case the ordinary arm governs exclusively the running of trains and the small arm those which refer to the shunting or loop line operations.

The *horizontal* position of the arms used for shunting (violet light) indicates danger; the inclined position (yellow light) authorises short operations which are sometimes controlled by a ground signal, and the *vertical* position (green light) gives permission for longer operations.

At intermediate stations provided with loop lines, the *inclined* position of the shunting signal allows shunting to take place, and its *vertical* position the running of trains into the loop.

E. *Direction signals.* — At branches and at stations the direction in which trains are to go is shown either by numbers working with one signal arm, or by means of *arms displayed horizontally* fixed side by side on a common support, or with a combination of these two systems.

The system of *direction numbers* is applied to signals at stations for trains that are standing (having come from platform lines, sidings, etc.), or to trains running at less than 40 km. (25 miles) per hour (entering stations backwards, platform lines, groups of sidings, etc.).

The route indicating signal therefore is composed of an ordinary arm with numbers (which can be either figures or letters). These numbers coincide with the directions given in the special instructions.

When the arm is at danger, the numbers are concealed by means of a plate, and when it gives line clear, a number appears showing the direction the train has to take.

When the signal carries an arm for shunting purposes, numbers may also be shown, when this arm is giving line clear, in order to show the direction in which the operation is to take place.

The system in which the *arms are displayed horizontally on brackets or gantries* is used at branches, entrances to stations and in a general way at points where trains run at a speed above 40 km. (25 miles) per hour (fig. 9).

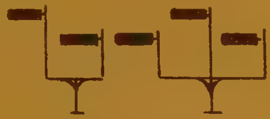


Fig. 9.

Semaphores on brackets or gantries have short posts each carrying an arm and fixed on to a common support. The left hand post governs the line (or group of lines) to the left; that on the right deals with the line (or group of lines) to the right, while the middle post that, or those, in the centre.

The arm which applies to the straight road is placed higher than the others unless the same speed may be maintained in all directions, whether this be normal or reduced; in this case all the arms are fixed at the same level.

If shunting operations have to take place in one of the directions governed by the bracket signals, a shunting arm is added to the post corresponding to this direction.

The *numeral system combined with horizontally placed arms* is used for indicating the various roads of a same

group of lines (for instance, platform lines of a passenger station) (fig. 10).

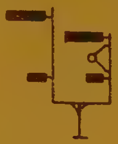


Fig. 10.

This system explains itself. It is only necessary to know that in this case numbers are fixed to the post corresponding to a particular group of lines to which they give entry.

The distant or back signal which corresponds to a point where slowing up is obligatory takes two positions : horizontal for a stop, and at an angle of 45° for line clear. It is thus possible, without any additional expense, to remind the driver that he will find a speed limiting post near the home signal.

The distant signal corresponding with a signal indicating direction is fitted with only one arm with arrow head working in three positions. The numbers giving direction are not repeated.

If the arms of bracket semaphores at a junction are fixed on the same level, the inclined position of the distant signal indicates that it is necessary to slow up for all directions (fig. 11*a*) and if vertical, the speed allowed for this combination of lines may be maintained (fig. 11*b*).

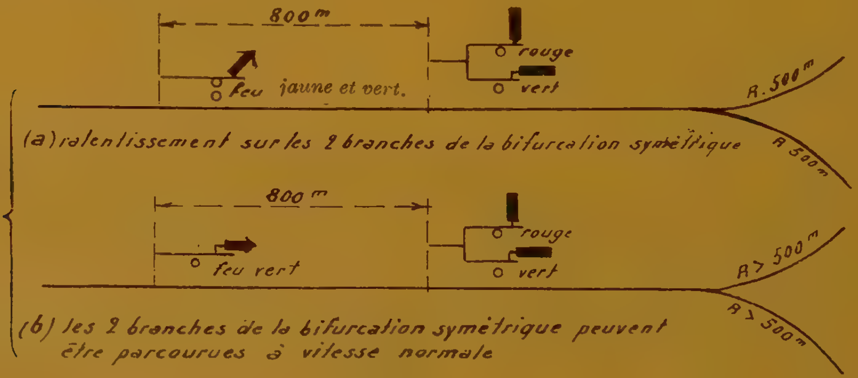


Fig. 11.

Explanation of French terms : Feu = Light. — Jaune et vert = Yellow and green. — Rouge = Red. — Vert = Green. — (*a*) Ralentissement, etc. = (*a*) Slowing on the two branches of the symmetrical junction. — (*b*) Les 2 branches de la bifurcation symétrique, etc. = (*b*) The two branches of a symmetrical junction can be run over at normal speed.

§ 3. — Combined signals.

If two home signals are placed at a distance of less than 1 000 m. (1 093 yards) from each other, the indications given by the front signal are repeated by the rear signal according to the following rules :

A. — The front signal having only one ordinary arm. The inclined position of 45° of the arm of the rear semaphore indicates that the arm of the front signal is at danger, and if vertical, at line clear (fig. 12).

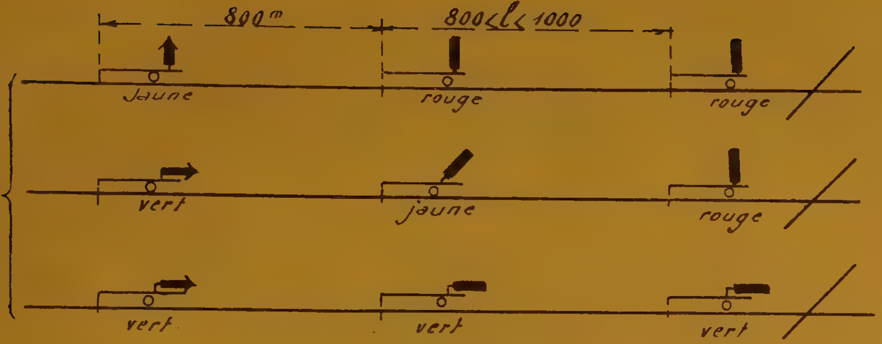


Fig. 12.

Explanation of French terms : Jaune = Yellow. — Rouge = Red. — Vert = Green.

B. — The advance signal is a bracketed one. The only rear which indicates the position of the advance home signal is placed below the arm of the rear home signal; this combined signal arrangement gives the four directions shown in figure 13.

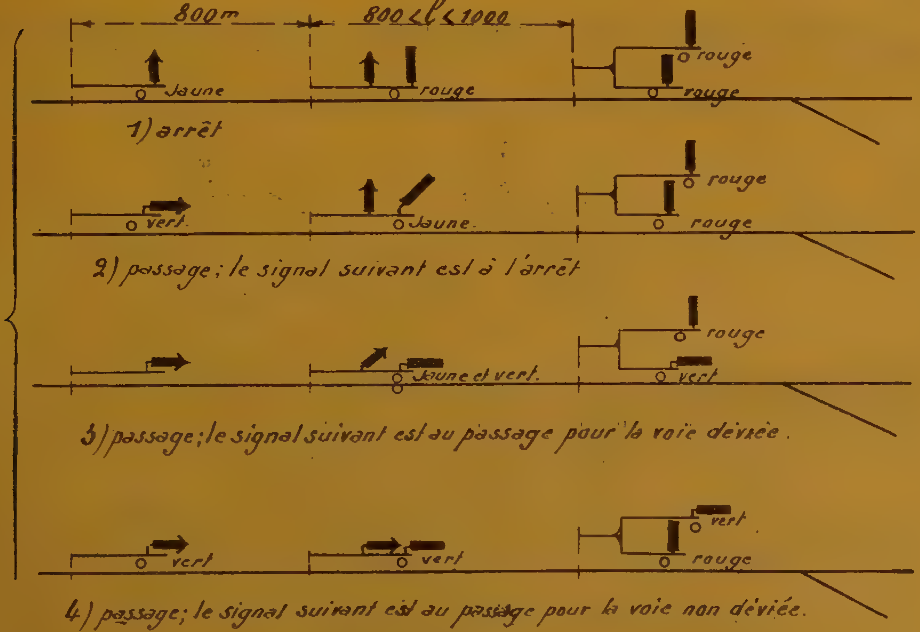


Fig. 13.

Explanation of French terms : Jaune = Yellow. — Rouge = Red. — Vert = Green. — Arrêt = Danger. — Passage; le signal suivant est à l'arrêt = Line clear; the next signal is at danger. — Jaune et vert = Yellow and green. — Passage; le signal suivant est au passage pour la voie déviée = Line clear; the next signal is giving clear for the branch. — Passage; le signal suivant est au passage pour la voie non déviée = Line clear; the next signal is giving clear for the straight road.

The indications for night signals are given in figures 12 and 13.

The combination of the signals in case of a symmetrical junction is arranged according to the diagrams in figure 14.

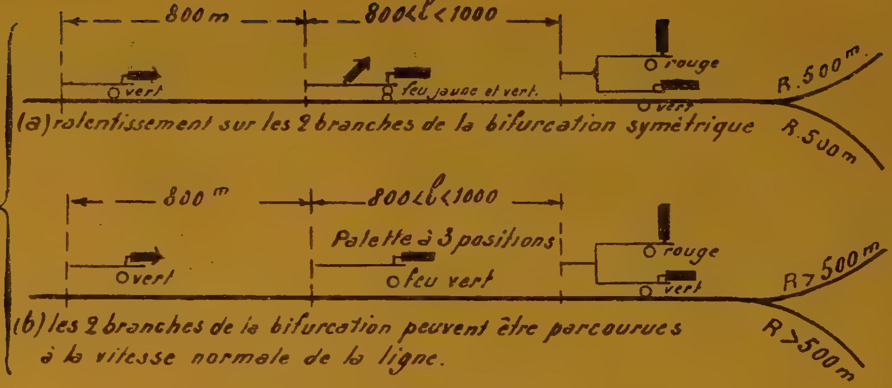


Fig. 14.

Explanation of French terms : Vert = Green. — Feu jaune et vert = Yellow and green light = Rouge = Red. — (*a*) Ralentissement, etc. = (*a*) Caution for the two branches of the symmetrical junction. — (*b*) Les deux branches de la bifurcation peuvent être parcourues, etc. = (*b*) The two branches of the junction may be run into at normal speed allowed for the line. — Palette à 3 positions = Signal with three positions. — Feu vert = Green light.

C. — If the rear signal is itself a bracketed one, the same rules are applicable for each part of it (fig. 15).

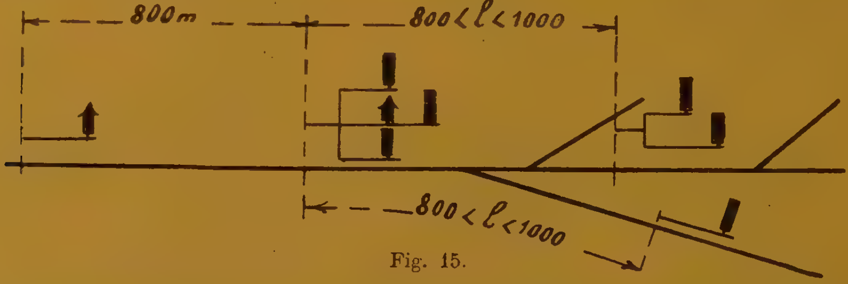


Fig. 15.

In this example the left hand arm of the bracket has two positions, horizontal and vertical; the right hand arm three positions, horizontal, vertical and inclined; the

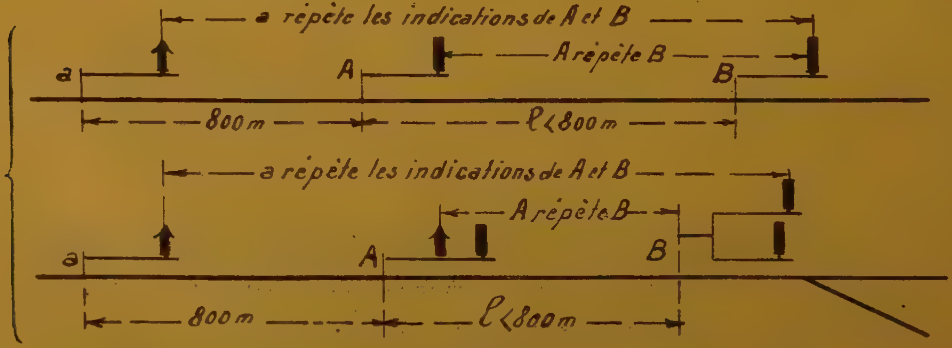


Fig. 16.

Explanation of French terms : *a* répète les indications de A et B = *a* repeats the indications of A and B. A répète B = A repeats B.

middle post is able to indicate the four positions, as in the case shown in figure 13. If the distance between the two home signals is less than 800 m. (875 yards) the indications of these two semaphores may be repeated by the preceding distant signal (fig. 16).

The distant signal *a* is a three positioned one. It is horizontal if *A* is at danger, at 45° if *A* gives line clear and *B* is at danger, and vertical if *A* and *B* show line clear. The driver is advised in time if he is to slow up at signal *A*, in order to make certain of stopping at *B* if this is at danger.

CHAPTER III.
Practical applications.

In this chapter the signal arms shown in the various diagrams are represented by the sketches shown in the following table.

Classes of arms.	Aspects.	True form of arms.	Meaning.
 *Two-position* danger arm.	1° *horizontal.*		Stop.
	2° *vertical.*		Proceed.
 *Three-position* danger arm.	1° *horizontal.*		Stop.
	2° *vertical.*		Proceed.
	3° *inclined at 45°.*		Caution; next signal at danger.
 *Two-position* distant signal.	1° *horizontal.*		Caution; next signal at danger.
	2° *inclined at 45°.*		Attention. — Reduced speed at next signal.
 *Two-position* distant signal.	1° *horizontal.*		Caution; next signal at danger.
	2° *vertical.*		Proceed at normal speed; next signal off.

Classes of arms.	Aspects.	True form of arms.	Meaning.
 *Three-position* distant signal.	1° *horizontal.*		Caution; next signal at danger.
	2° *inclined at 45°.*		Attention. — Slow up for next signal.
	3° *vertical.*		Proceed at normal speed.
 *Three-position* distant signal.	1° *horizontal.*		Caution; next signal at danger.
	2° *inclined at 45°.*		Attention. — The first home signal in front is off, but the second less than 800 m. further on is at danger.
	3° *vertical.*		Proceed at normal speed; both signals are off.
 *Three-position* distant signal.	1° *horizontal.*		Caution; next signal at danger.
	2° *inclined at 45°.*		Attention; slow up for next signal either because the arm relating to the branch line is off or because the arm relating to the straight line shows that the following signal is at danger.
	3° *vertical.*		Proceed at normal speed; next signal is off for normal speed.
 or  Two armed signal, one of which is a distant.	1° both *arms horizontal.*		Stop.
	2° Danger *arm* inclined at 45° and distant *signal horizontal.*		Caution; next signal at danger.

Classes of arms.	Aspects.	True form of arms.	Meaning.
or  Two armed signal one of which is a distant. (*Continued*). or 	3° Danger *signal vertical* and *distant signal inclined at 45°.*		Attention.
	4° both *arms vertical.*		Proceed at normal speed.
 Small *two-position* rectangular arm.	1° *horizontal.*		Stop.
	2° *inclined at 45°.*		Shunting.
 Small *two-position* rectangular arm.	1° *horizontal.*		Stop.
	2° *vertical.*		Put by into siding or loop.
 Small *three-position* rectangular arm.	1° *horizontal.*		Stop.
	2° *inclined upwards at 45°.*		Short or limited shunting operation.
	3° *vertical.*		Shunting without reserve, or put by into loop.

§ 1. — Dangerous points on main line.

1° Simple case at which danger may arise.

Level crossing much used, swing bridge, halt, or block post.

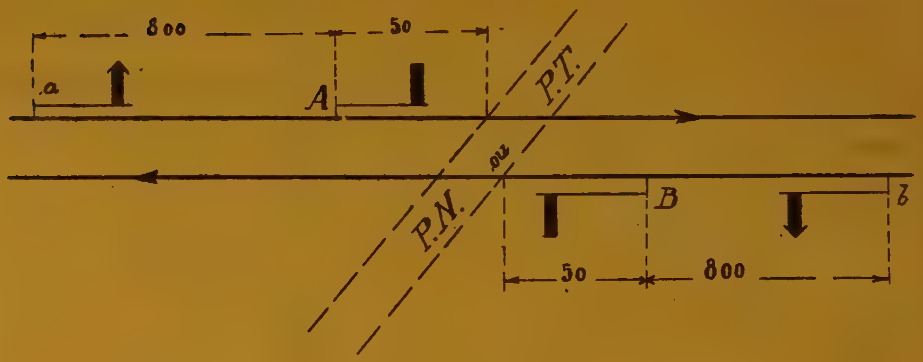


Fig. 17.

2° Case of two boxes near to one another.

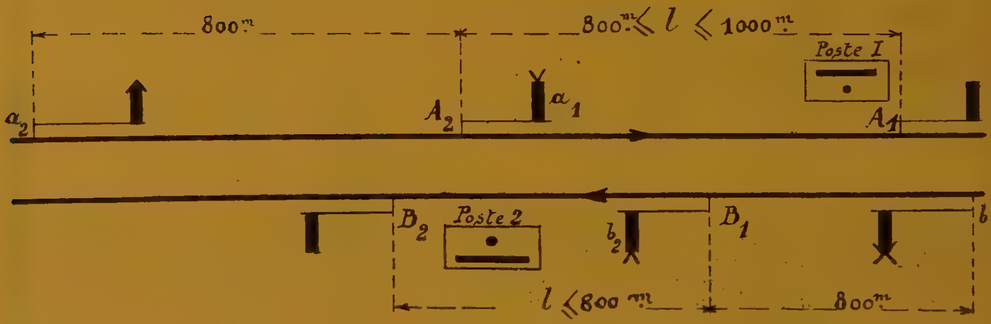


Fig. 18.

3° Case of a junction.

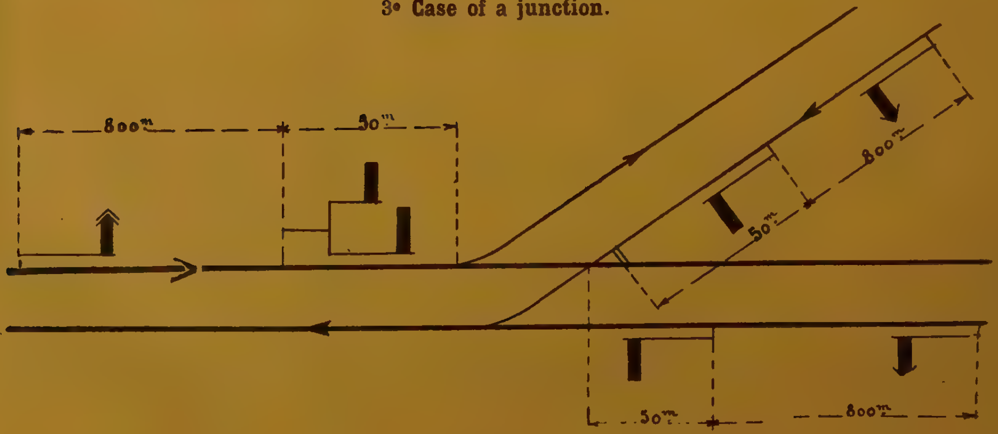


Fig. 19.

4° Case of two successive junctions less than 1 000 m. (1 093 yards) apart.

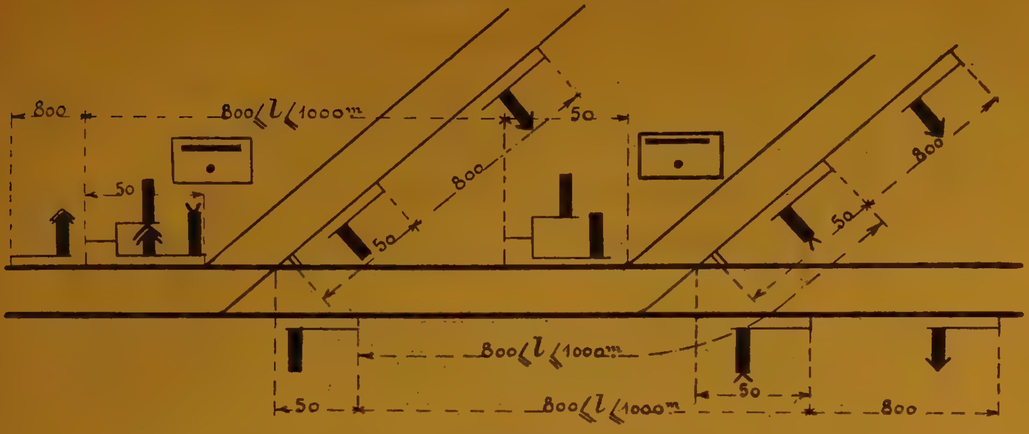


Fig. 20.

5° Case of two successive junctions less than 800 m. (875 yards) apart.

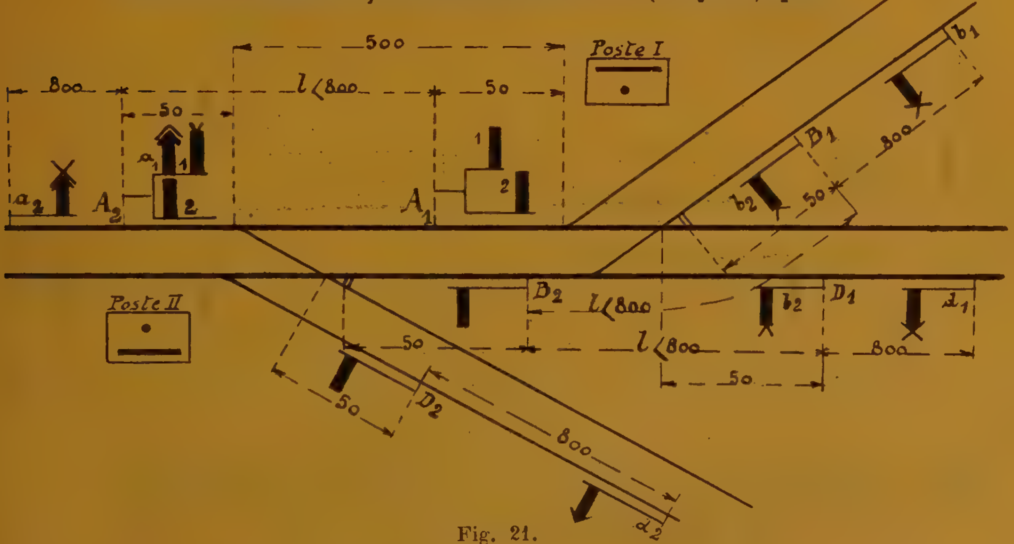


Fig. 21.

§ 2. — Signalling at intermediate stations.

1° Stations without loops for trains.

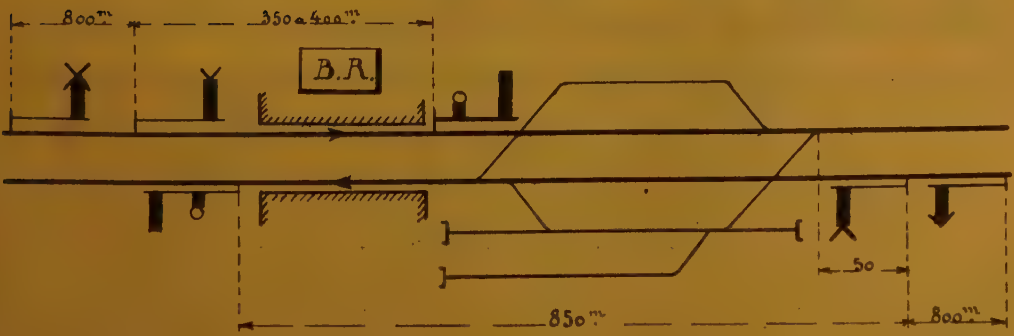


Fig. 22.

2° Stations with loop lines.

a) Backing into a loop.

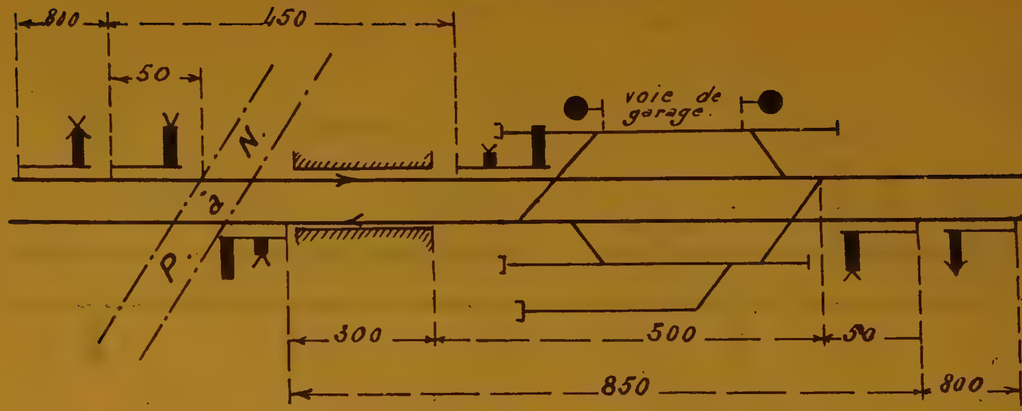


Fig. 23.

Explanation of French terms : Voie de garage = Loop line.

b) Running directly into a loop from one of the lines only.

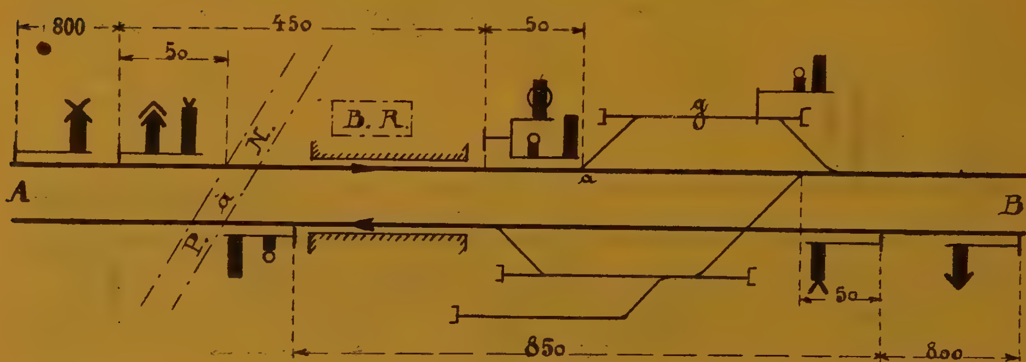


Fig. 24.

c) Running directly into a loop from both directions on either line.

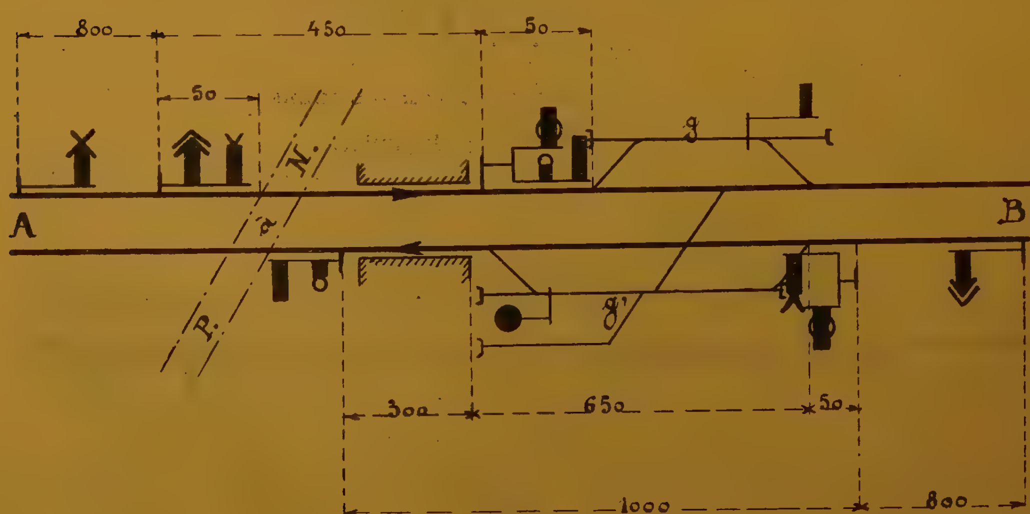


Fig. 25.

§ 3. — Signalling at passenger stations.

a) Through station of little importance.

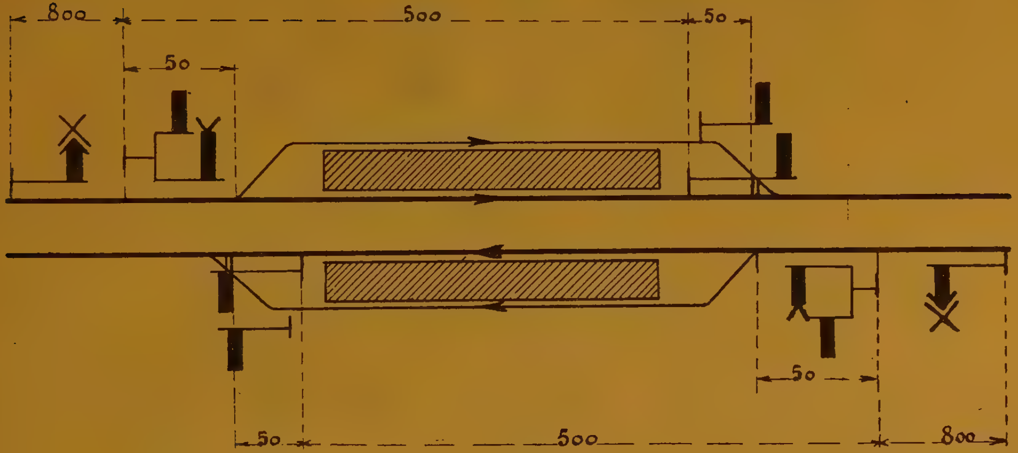


Fig. 26.

b) Important through station.

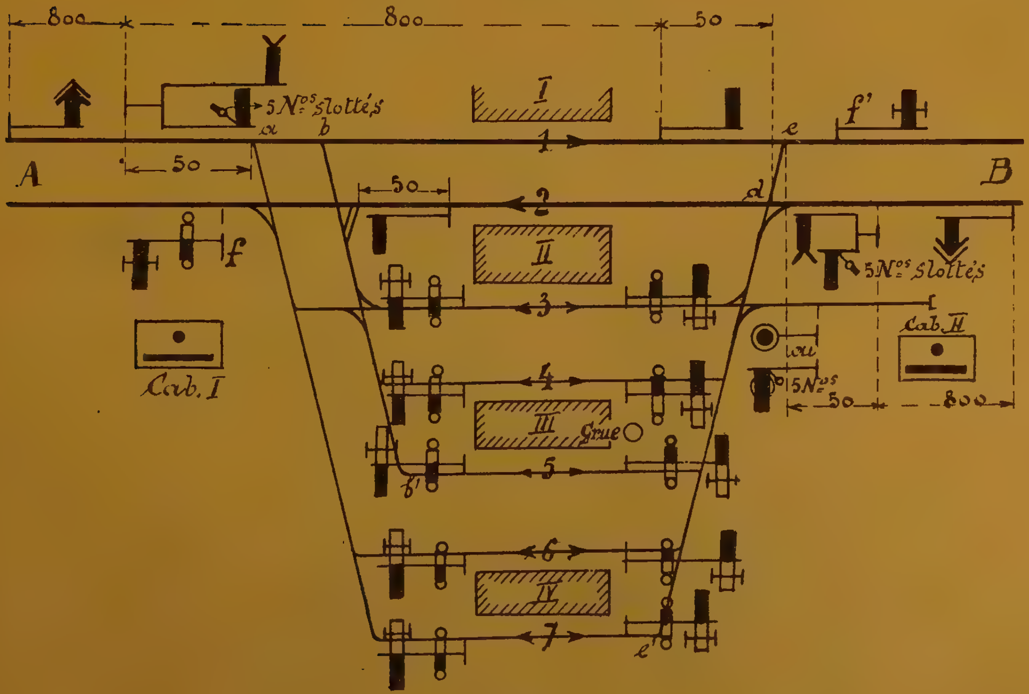


Fig. 27.

c) Large junction station.

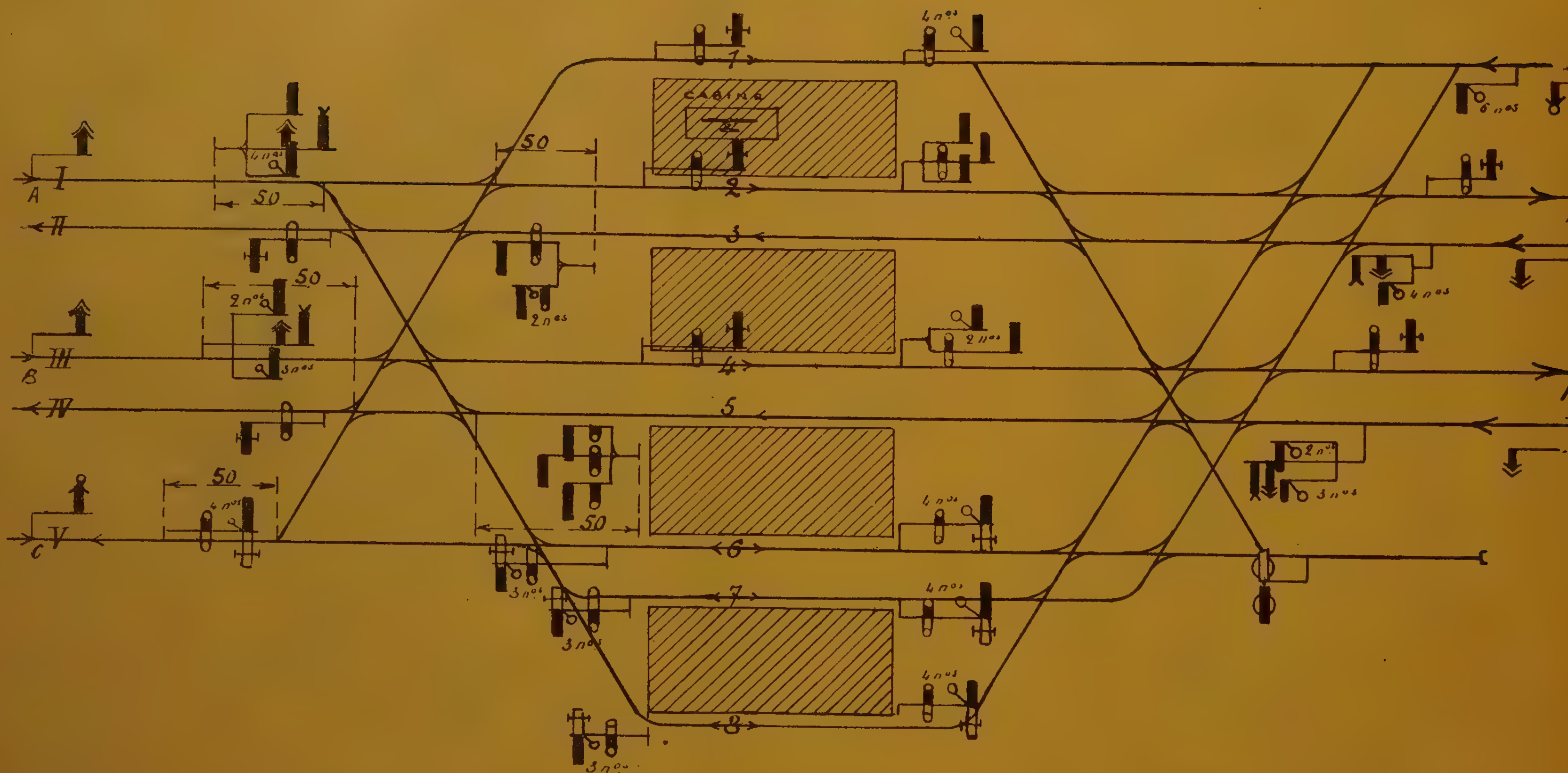


Fig. 28.

d) Backing in station.

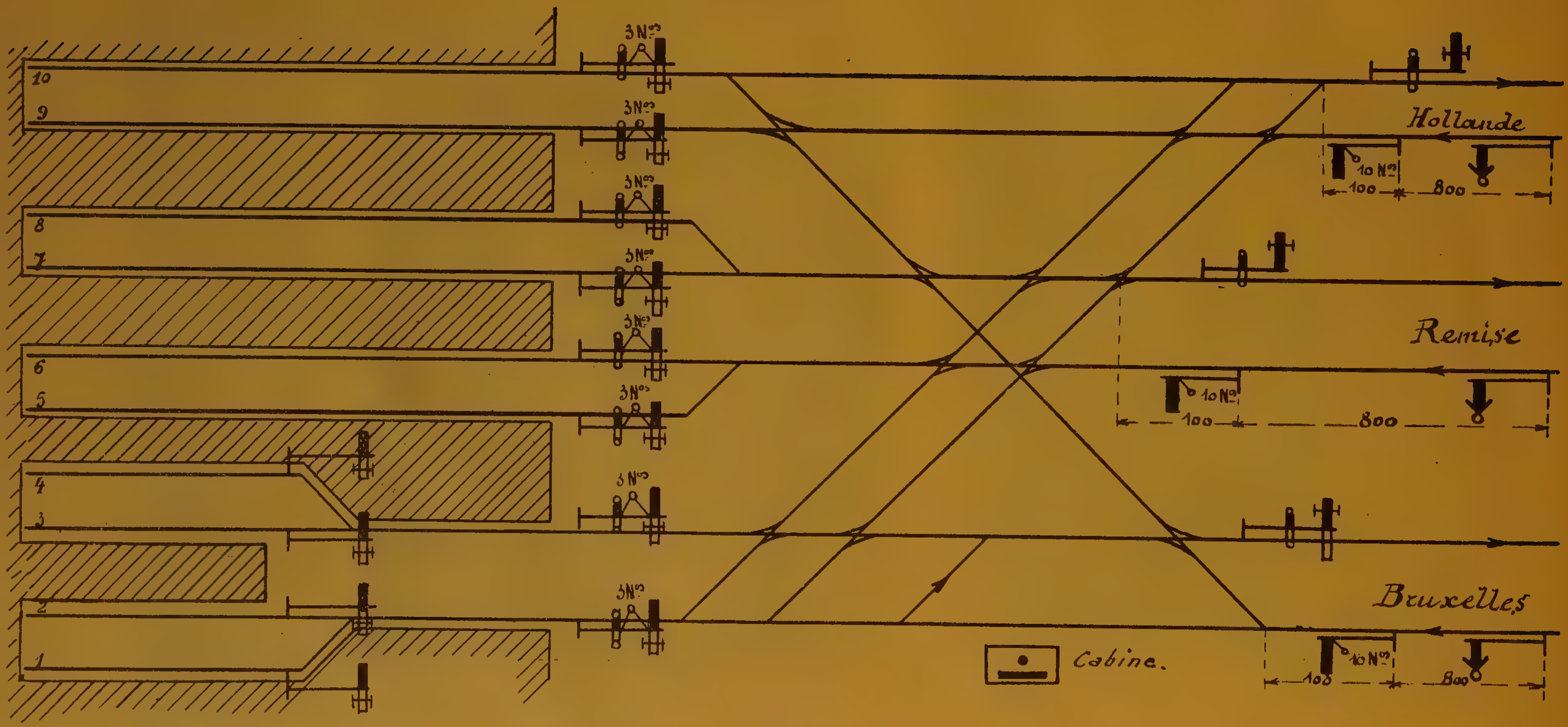


Fig. 29.

[621 .33 (.44)]

Opening of the Pau-Lourdes line by electric traction,

By E. UYTBORCK,
HONORARY ENGINEER OF THE BELGIAN STATE RAILWAYS.

Figs. 1 to 3, pp. 442 and 443.

Readers of the *Bulletin* will find below some photographs which complete the information contained in the article which appeared on page 43 of the January 1923 number.

Figure 1 represents a view of the outside portion of the sub-station at Coarraze-Nay, in which will be seen some interesting details of the aerials and of the single pole oil break circuit breakers for the primary current of 60 000 volts.

Fig. 1.

Figure 2 is a view of locomotive 4002 and its train decorated for the official opening.

Figure 3 gives an exterior view of the same locomotive; the lateral equalising gear of the bogies will be noticed. This is a new device adopted by the « Société des Constructions électriques de France », and which appears to be coming more and more into common use.

Fig. 2.

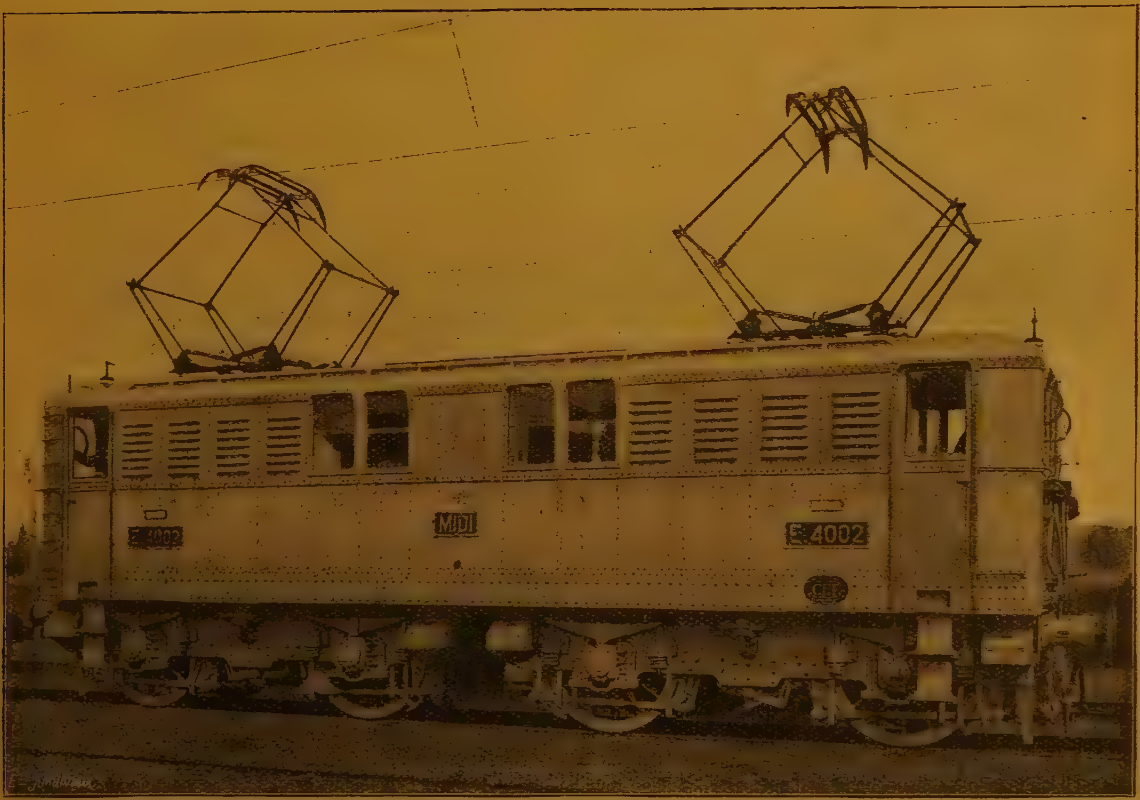


Fig. 3.

[625 .13]

The renewal of bridges, (1)

By B. P. FLETCHER, A. M. Inst. C. E. (Assoc. Fellow).

Figs. 1 to 15, pp. 447 to 449.

(*Journal and Report of Proceedings of the Permanent-Way Institution.*)

To the casual observer there occurs to be little to require much thought or judgment in the design and erection of bridges of moderate span on new work and still less for their renewal. In the following pages the Author will endeavour to show that in many respects the renewals of bridges of even the shortest span requires more consideration as regards design, method of erection, etc., than was required when they were first erected. Generally speaking in entirely new work erection is handicapped by difficulties of transport of materials, but when the materials are once on the site the parts may be assembled without interruption of railway traffic. On the other hand in the case of renewals there is little trouble as regards transport to the site, but the work of fixing requires the following items to be considered :

a) Existing traffic; *b*) Existing structure; *c*) Most suitable design; *d*) Most suitable method of erection; *e*) Time available for erection; *f*) Encumbrances, pipes, cables, etc.

The above items are often a serious handicap and necessitate the work being done under conditions entirely absent in new work.

In the remarks which follow, it is assumed that a railway either runs over or under the bridge or that a railway runs both over and under the bridge.

The design of a bridge is dependent upon the traffic, method of erection, time available for erection and cost. As the method of erection also depends upon the traffic, the several ways of dealing with and working traffic will be first considered, *e.g.:*

1. Diversion by another route.

2. Half bridge renewed at one time and traffic worked by single line between two signal cabins. (Fig. 1.)

3. If the section be long and the work be carried out during the week over a long period, time may be saved by erecting temporary signal cabins and cross over roads near the site, thus reducing the section worked by single line. This requires inspection by the Government. (Fig. 2.)

4. To avoid extra facing cross over roads at the ends of single line section the up and down lines may be linked to form a continuous line. (Figs. 3 and 4.)

5. Temporary single line bridge, generally composed of part of old bridge, raised high enough to allow of new cross girders being placed in position. (Fig. 5.)

6. False work erected to take the load of traffic, while old girders are removed and new ones placed in position.

(1) Paper read at London Sectional Meeting, 16 December 1921.

7. Transferring passengers from one train to another by temporary gangway over gap.

8. In the case of road traffic arrangements must be made to renew half the bridge at one time, leaving the other half open for traffic.

9. A temporary timber road bridge may be erected and traffic diverted while the whole bridge is renewed; this is essential when width of road is narrow.

Interlacing of tracks.

The term « single line working » for temporary work in principle is the same as that adopted on single line branches, the main difference being that the usual staff or tablet is replaced by a pilotman, except where there is much traffic and work is likely to take a long time then staff or tablet instruments are temporarily erected.

The method of erection.

1. In the case where traffic is diverted then the work may be conducted similarly to new work.

2. By cranes situated on opposite sides of the span on the line which is blocked, the new girders being brought by train along the single line and lifted from the wagons and placed in position. One half is then completed and single line working is then transferred to the new portion while the second half is similarly dealt with. For this method it is necessary that the troughs or girders span the gap unless there be a centre main girder when cross girders may be used.

3. By suspending the new main girders from cross girders resting on trestles fitted on wagons which are run over a temporary single line bridge, the new girders projecting clear of the temporary bridge. When safely over the abutments the girders are packed up, the wagons removed, and then the girders are jacked along the abutments into position, one being left rather wide to admit the cross girders, or trough floor. The cross girders or troughs are then lowered on to the ground below and raised into position by cranes working on opposite sides of the temporary bridge. The temporary bridge is raised high enough to allow this to be done. (Fig. 6.)

4. By erection on temporary work at the side of the site and rolling the whole of the new bridge into position on ball bearings. To do this winches may be required or by coupling a rope to a crane or locomotive and passing it over a snatch block, fixed axially to the direction of motion, the crane or locomotive may haul it into position. To do this it is necessary to stop all traffic. If only a portion of the bridge can be done at once then temporary staging must be erected on both sides. (Fig. 7.)

5. If the bridge be over a river then it may be possible to float the girders over the span by transferring one end of the girder to a stool fitted on to a boat the other end remaining on a bogie running on rails square with the abutments. In doing this precautions must be taken against oscillations caused by the river traffic. (Fig. 8.)

6. In some cases it is desirable to erect the new structure on false work. This method is suitable for cases when owing to the size and weight of girders it is impossible to bring them on to the site complete or they are too heavy to be lifted by cranes. Also in cases when false work is necessary to take the load of traffic, the erecting platform may be added with but little extra cost. (Fig. 9.)

7. In some cases the new structure may be built excentrically along-side the existing work, the old and new work

interlacing each other. This only reduces the width of bridge available for traffic by rather more than the width of one of new main girders. When the new bridge is completed the old one is dismantled and the new one jacked into its permanent position. (Fig. 10.)

8. Sometimes a larger structure is required as, for instance the doubling of a single line of railway or a wider thoroughfare, then the new structure may be erected around the existing one without interfering with the traffic except while the existing structure is being removed. (Fig. 11.)

In the case of single line branches one of the foregoing methods of erection may be modified to meet the special requirements.

When designing a bridge it is necessary to bear in mind the method of erection to be adopted so that during erection the girders are not unduly strained and the stresses reversed in the members. Additional temporary members sometimes have to be added to safeguard this.

The question of time available for doing the work is also an important item. Traffic again has to be considered and invariably the bulk of the work has to be done at weekends. Advantage is taken of the long days, strikes, pay weeks in mining districts, holidays, etc. Unfortunately on Sundays although the regular traffic is considerably less than on week days delays are often caused by having to clear the single line and send the pilotman and engine to take the Theatrical Specials, excess loads, special goods, etc., over the effected section and some time elapses before the pilot is able to bring into position the necessary wagons for unloading, etc. To save time a pilot engine with pilotman on board is generally coupled to trains during single line working.

The cost of renewal of bridges has generally to take a secondary place as the work has to be done very often under unfavourable conditions, but it can be very largely reduced by adopting suitable designs and methods of erection and by amicable arrangements for dealing with the traffic, which is the chief cause of hindrance and delay.

The bridge to be renewed may be built of timber, masonry, cast iron, or wrought iron.

Timber bridges are generally erected where first cost is the chief consideration, especially in undeveloped countries where timber is plentiful and transport is difficult and it is necessary to hasten erection, the ultimate intention being to renew in more permanent material when the line justifies further expenditure. In some cases timber viaducts are constructed over ravines when the line is first constructed, the intention being to gradually fill in the ravine and when the viaduct is ready for renewal it is dismantled and the track laid on embankment, which in the meantime has consolidated. Except in the cases mentioned timber is now rarely used in permanent structures, but is the most useful material for temporary work as it can be so readily handled and cut as required on the ground.

Brick and stone almost exclusively used for abutments and piers although in the latter case they are sometimes replaced by cylinders or columns according to circumstances such as bad foundations, etc. Concrete is largely used for foundations and sometimes abutments. Owing to the difficulties and time required to build arches of brick or stone it is impossible to renew them except where the headway is great enough to allow the centering being fixed clear of the load gauge, also owing to the necessity of having to erect a temporary bridge to carry the traffic it is the general practice, at any rate in the case of railways, to renew them in wrought iron or steel. If they be over bridges there is a decided advantage as

Fig. I

Fig II

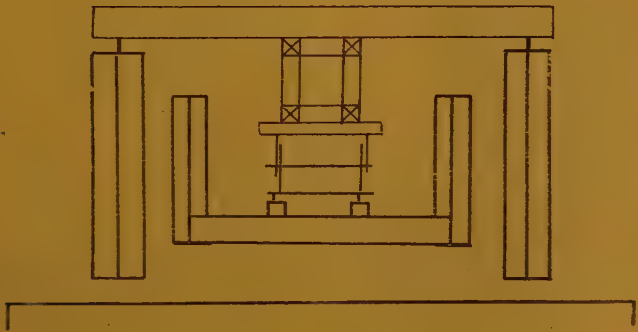
Fig III.

Fig IV

Fig V.

Fig V a

Fig VI.



Figs. 1 to 6.

FIG VII

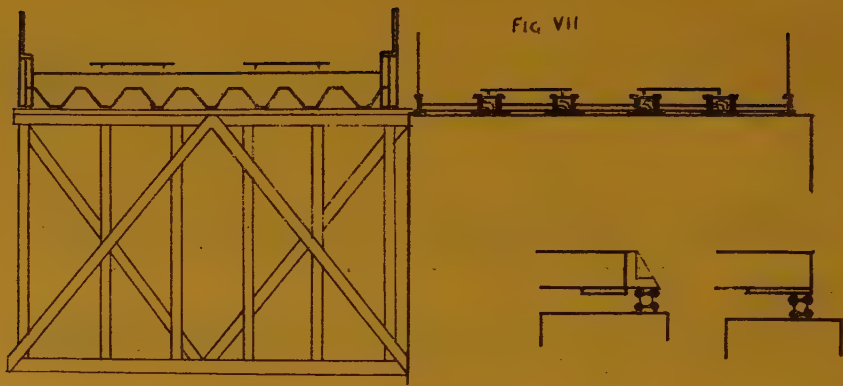


FIG VIII

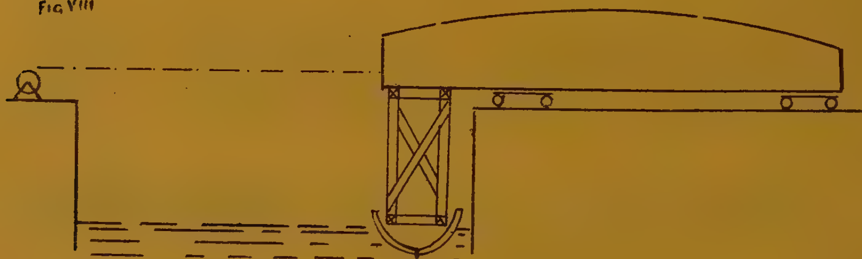


FIG IX

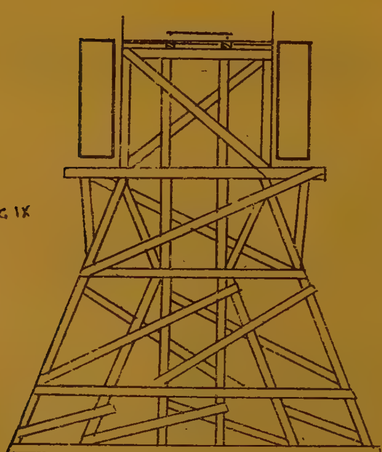
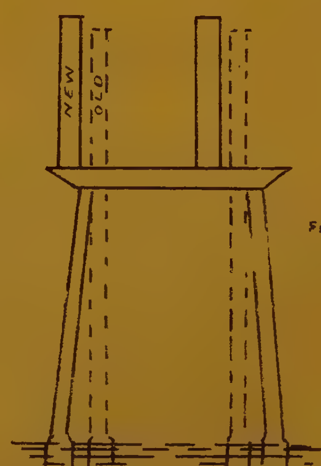


FIG X



Figs. 7 to 10.

FIG XI

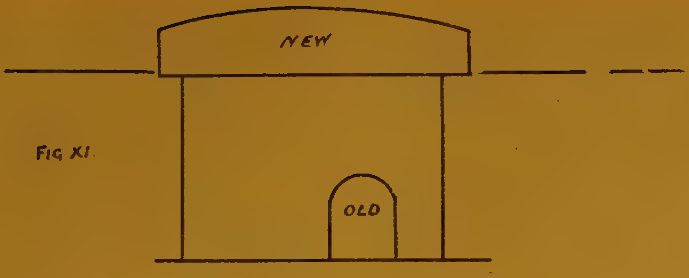


FIG XII

FIG XIII.

FIG XIV

FIG XV

Figs. 11 to 15.

the arch is the chief obstacle in the way of increasing the load gauge and parallel girders also give the driver a better chance of seeing ahead as the haunches of the arch obscure his view. The practice of building an arch of brick and facing voussoirs of stone is not recommended as experience has shewn there is a decided tendency to separate the arch from the voussoirs, due no doubt to the live load, and if an arch be decided upon the ring should be either all brick or all stone. In districts where subsidences due to pitfalls, etc., are prevalent the masonry arch is not to be recommended as the settlement may be irregular and the arch ring will be fractured, on the other hand however girders may be packed up. If an arch be built of brick or stone of good quality and does not weather, it will last longer and require less attention than a girder bridge of wrought iron or steel which requires to be painted about every five years. This is a great saving from a maintenance point of view.

Cast iron for girder work in tension when subjected to live loads is now prohibited by the Board of Trade and is rarely now used for the removal of bridges although it may still be used for compression flanges and arched ribs.

Wrought iron in bridges is now being replaced by mild steel owing to the

greater tensile stress and homogeneity of the latter, although wrought iron withstands corrosion better than steel.

Mild steel is now the most favoured material for bridges and is extensively used for bridge renewals.

When it is decided to renew a bridge, the chief points to bear in mind are ;

1. The causes for renewal;

2. The opportunity for improving alignment;

3. Additional clearances for perspective enlargement of load gauge;

4. Avoid defects observed in existing structure;

5. Efficiency with economy.

1. The causes for renewals are :

a) General decay of materials due to exposure to weather, moisture, bad drainage, etc.

b) In the case of masonry arches owing to uneven settlement the arch ring may have become fractured or owing to insufficient packing between sleepers and crown of arch, the key stone may have become crushed owing to the load not being sufficiently distributed. This latter defect may be partially releived by putting in way beams.

c) Members may be too highly stressed owing to increase of axe loads. During the past 25 years the axle loads have increased 25 %, the result being that structures erected then have to bear greater loads and are especially weak in the cross girders.

2. Renewals frequently offer opportunities to improve the alignment and it is important that this should not be overlooked.

3. On some of the early lines what is now considered sufficient clearance was not anticipated and renewals give an opportunity of increasing the clearance.

4. The defects may be :

a) The design. As the structures are generally thirty to fifty years old, the material now in use, modern practice, and increased axle loads generally demand a different type of structure. However a study of the design of existing structures especially the early wrought iron bridges is well worth attention, noting particularly the alignment of top booms, working of rivets, rivetted joints, corrosion bearings, etc.

b) Lack of precautions against decay and corrosion due to exposure to weather, moisture and bad drainage. The vital parts of a structure should always be protected against liability to corrosion. In wrought iron and steel structures ample provision must be made to drain off water. If an over-bridge smoke plates should be provided to protect bottom flange and cross girders from corrosion due to steam and smoke. If an under-bridge then, as it is now the preferred practice to have a sleeper track instead of way beams owing to the difficulty of keeping the ends of the beams packed up and breaking the continuity of the sleeper track, it is necessary to have ballast on the bridge and ballast plates should be provided to protect webs from corrosion; this is especially necessary were coke breeze ballast is used owing to the presence of foreign substances, which attack the plates. It is preferable to use gravel ballast on bridges as it also tends to assist drainage. The decking or troughs should be protected by asphalte prior to laying the ballast. In damp swampy districts where vapour is continuously rising it is desirable to increase the flange areas, etc.

c) *Drainage.*— In the case of masonry arches the ring and haunches are covered with asphalte and the water is drained off at the back of abutments through dry filling and weepholes, clay filling at the back of abutments should always be avoided. On masonry viaducts a covering of asphalte is also used and the water is drained into channels on the piers and thence through pipes. Man-

holes should be provided at piers for inspection purposes. On old bridges clay puddle was used instead of asphalte.

In the case of steel or wrought iron structures advantage of gradient should be taken to drain one way, drip plates should be provided on through decks so that water may fall behind the abutments clear of the bedstones otherwise some of the water will find its way down the face of the abutments. To avoid this nuisance the back of the bedstones may be chamfered. On large bridges with no fall the drainage is most easily effected by decking it with dished plates, drilling holes for the drainage of water which may either fall freely or be conveyed away in pipes in cases over roads. These holes generally get filled up with small coal and cinders and should be periodically cleaned out. If troughing be used instead of cross girders and decking it is general practice to fill it with breeze concrete and then cover with a layer of asphalte about an inch thick and drain towards the abutments by increasing the camber. The ends at abutments are built up with brick or stone and the asphalte is continued over to the back of abutments and the water is drained away behind. It is necessary for the asphalte to be fairly plastic to allow for deflection and working between the steel and masonry.

The bottom booms of large girders where water is likely to lie between the double webs, should have holes drilled for drainage and be protected with asphalte.

In some old bridges difficulty has been experienced in preventing water from falling down the face of abutments, partly due to the pumping action of the way beams in the troughs. By providing a drip of sheet lead inserted below the bedstones and running a spout along the abutment the road below may be kept dry or corrugated iron may be used over the affected area.

The bearings of girders are important. In long span bridges where expansion and deflection is considerable, expansion roller bearings and fixed bearings are used. For short spans where expansion and deflection are small generally 1/2 inch to 1 inch bearing plates are used, the rivets on the underside being countersunk. In order to remove any uneven pressure between bearing plates and bedstones, due to the unevenness of the stone, etc., the surface between is either flushed with grout or as this takes time to set in the case of renewals sheet lead or felt is generally used. For main girders, granite bedstones are used and for cross girders either granite or good quality freestone.

The question of filling troughs with concrete is also important, when traffic has to be run over immediately, as it has no time to set if put in the same day, so for this reason method of erection 4 is to be recommended for moderate spans as this enables the whole bridge to be assembled, troughs filled with concrete and asphalte prior to the actual day of renewal and gives the concrete time to set, or method 3 may be used for the same purpose in the case of larger spans. In urgent cases where it is absolutely necessary to run traffic over immediately and the above methods cannot be adopted the troughs are filled with asphalte concrete, composed of asphalte and stone chippings — this sets quickly.

Reference has been made to encumbrances other than traffic in the form of Cables, third rails, gas and water pipes, point rodding and signal wires, telegraph wires and care should be taken that none of these items, if any, are overlooked. When once a bridge is erected it is often found convenient to carry one or more of the above over it and when it is time for renewal it is important to ascertain what passes over the bridge other than the ordinary traffic so that arrangements can be made to temporarily cut off supply at least for a sufficient time to erect

a portion of the bridge. In cases where it is impossible to cut off supply then temporary diversions may be made or the pipe or cable held in position by trestles. Telegraph wires are often a nuisance as they interfere with the jibs of cranes.

Repairs to masonry viaducts.

Well built masonry viaducts hardly require much attention, but if the drainage at the piers has been inadequate or the pipes have become choked water settles between the haunches and the lateral pressure causes the spandrels to bulge. This necessitates tie rods and wall plates being fixed and providing efficient drainage.

In girder viaducts each span can be renewed separately adopting one of methods mentioned for renewal of bridges or some modification according to circumstances.

Repairs to tunnels.

Sometimes through weakness or increased load the roof gives way or shows signs of weakness and repairs have to be effected. If the contour of the tunnel be large enough a cast iron lining may be fixed within the existing arch at the affected portion, without affecting the load gauge, this is generally the easiest to adopt or the brick or stone lining may be strengthened and rebuilt, this however, will require centering which either means blocking the tunnel or if contour be large enough laying a single track along the centre and erecting the centering over and around the affected portion clear of the load gauge of the single track.

Reference has been made to steel troughing for floors of bridges under the heading of drainage. The exact form this should take depends on circumstances. A few years ago it was built up of plates and angles or T irons, now it is most generally made of steel plates pressed into troughs of various depths and sections and joined together with cover strips. It is desirable that as much rivetting as possible should be machine done to ensure the rivets completely filling the holes and to save time and expense on the ground as much as possible should be done in the yard. Several troughs may be brought on to the spot rivetted together thus leaving only a few rows to be done on the site. When the headway is small and it is impossible or inconvenient to erect scaffolding for rivetters underneath it is necessary to do all the rivetting on the top of the bridge so one of the following devices is adopted either as in figure 13, all the rivetting may be done on top and this type also has the merit of not having ledges as in figures 12 and 15 for moisture and soot lie on, or as in figure 14 is adopted but instead of a cover strip two angles are used.

625 .4 (.42) & 625 .13 .42)]

Some facts about the construction of the London Tube Railways, [1]

By Harley H. DALRYMPLE-HAY, M. Inst. C. E.

Figs. 1 to 5, pp. 457 to 467.

(*Journal and Report of Proceedings of the Permanent-Way Institution.*)

No account of the construction of the London Tube Railways would in itself be complete without some reference to the early history and development of the shield system of tunnelling by which those railways have been so largely constructed.

The history of tunnelling by means of a shield dates from the year 1823, when Marc Isambart Brunel, a Frenchman by birth, who subsequently became a citizen of the United States by choice, but died an English Knight, commenced the construction of a tunnel between Rotherhithe and Wapping under the River Thames, through which tunnel the trains of the East London Railway now pass. Before that time tunnels had been constructed in various kinds of strata, but without the use of shields, through hills, and mining at great depths had been carried on in some cases under rivers as well as under the sea; but in no previous instance had so large a tunnel been constructed close to the bed of a great tidal river as that under the Thames between Rotherhithe and Wapping.

It is not that no attempt had been made, for in the year 1798 a tunnel was commenced at Gravesend, also under the Thames, and again in 1805 another one was started by two Cornish miners named Vaizie and Trevithick near the site of the great work subsequently constructed by Brunel.

Unfortunately there are practically no records of the first work, but the published accounts of the second are of considerable interest, describing as they do the first serious attempt to construct a tunnel under a tidal river.

It is perhaps not quite accurate to say that the second was a serious attempt to construct a tunnel, for although the construction of a tunnel was contemplated, the actual work did not really get beyond the sinking of a shaft at some distance from one bank of the river, and the driving of a short length of timber heading under the river itself, when owing to the heading being seriously flooded on more than one occasion the work was stopped and ultimately abandoned.

Owing to the failure of these early attempts, no other similar project was brought forward until the year 1818, when Brunel proposed an entirely novel method of constructing tunnels, and suggested the application of his system to the construction of the then proposed tunnel between Rotherhithe and Wapping by means of an apparatus he called a shield.

Brunel was of course quite familiar with the manner in which Vaizie and Trevithick had constructed the trial heading at Rotherhithe already referred to, and recognised the desirability of forming the excavation in such a manner as not to displace more material at the working

(1) Notes of a lecture given at London Section, 17 October 1922.

face than would be subsequently occupied by the body of the tunnel itself.

The novelty of Brunel's idea consisted in providing a cell or casing to be forced forward in advance of the tunnel so as to protect the crown and sides of the excavation, and thus invented what he termed a shield. The Thames Tunnel was built of brickwork and consists of two tunnels side by side. It took seventeen years to build, and after enormous difficulties had been overcome was completed in 1840. The East London Railway Company purchased the Tunnel from the Thames Tunnel Company in 1865.

In the year 1862, Mr. Peter Barlow, an Engineer, and Professor of Mathematics at the Military Academy at Woolwich, was engaged in sinking the cast iron cylinders of the Lambeth Suspension Bridge near the Houses of Parliament. He found that there was no special difficulty in sinking the cylinders through the river bed, which consisted at that point almost entirely of the London blue clay. It accordingly occurred to him that it would be possible by suitable means to construct a cast iron horizontal cylinder, or in other words, a tunnel for a railway, in a like position. He took out a patent for his idea and wrote a pamphlet in the year 1867 describing a system of omnibus subways to be formed of cast iron tunnels, 8 feet diameter, in which the traffic would be carried underground in steel omnibuses each capable of seating 12 persons. The omnibuses were to be propelled by man power, aided by gravity, without stations (in the ordinary sense), the passengers paying in the omnibus.

The stopping places were to be at one level, and to provide for the differences of the surface level in the more elevated districts it was proposed to have three series of subways at different levels, the carriages as well as the passengers being lifted in passing from one to the other.

The first instalment of this system was realised in the construction of the small tunnel named the Tower Subway driven under the Thames near the famous fortress. Owing, however, to the difficulties encountered in the construction of Brunel's Thames Tunnel already referred to, Barlow could not get any responsible contractor to undertake to do the work, but his assistant, the late Mr. J. H. Greathead, whose name is so well known in connection with the London Tube Railways, came forward, and although an Engineer by profession and not a Contractor by trade, Greathead said to Barlow that he would take a contract for the work and construct the tunnel, which he did for the sum of £10 000.

Greathead applied himself with such energy that he completed his contract within the year 1869. The maximum speed attained was about 9 feet per day. The tunnel was wholly in the London blue clay and the men worked the usual three 8-hour shifts.

This subway is the first example of a cast iron shield driven tunnel anywhere in the world, and although constructed without any difficulties being encountered notwithstanding the fact that it was under the river, it is specially interesting historically as having led the way to the general adoption of the shield system of construction.

For a short time after the opening of the subway in 1869, passengers were transported under the Thames in a small car operated by a cable. Subsequently, as the scheme did not pay its way, the steam worked lifts giving access to the tunnel were replaced by spiral staircases, and passengers had to walk from one side of the river to the other through the tunnel.

The opening of the Tower Bridge in 1898 led to the subway being finally closed to traffic.

Following upon the construction of the Tower Subway, which Barlow and Greathead had so successfully completed, an Act of Parliament was obtained in

1884 authorising the construction of the City of London & Southwark Subway in two separate cast iron shield driven tunnels between King William Street City and the Elephant and Castle at Newington, Greathead being the Engineer.

The Subway was to be worked by cable traction and be equipped with hydraulic lifts.

Owing to the rapid advance of the application of electricity to traction purposes at that time, the Company decided to abandon the idea of working the subway with a cable, and in February 1890 commenced the experimental running of electric locomotives with two carriages on the City Section of the line, and so continued until the completion of the works which were opened to the public on the 18 December 1890, under the name of the City & South London Railway.

When the original scheme was before the Parliamentary Committees it met with a great deal of opposition, there being a large number of people who believed that not only was the capital of the company too small to construct the whole of the works for which powers were sought, but the capital was insufficient to complete even that portion of the two tunnels that was to pass under the river section alone, although in that position they would be wholly in the London blue clay.

In order therefore to prove their case in the most practical manner possible, the promoters decided in the first instance to commence operations by constructing a staging in the river over the centre line of the proposed railway, and from it to sink a shaft through the bed to the level of the proposed tunnels below, driving them north and south from that point.

The site of the landing stage and shaft are close to the old Swan Boat Pier which was just above London Bridge.

The advantage of this method of working as compared with a land site, facilitating as it did the removal by water carriage of all the excavated material, and the delivering by barges of everything required in the execution of the work, was so great that it has since been repeated in the case of the Waterloo & City Railway and again in that of the Baker Street & Waterloo Railway with the greatest advantage and convenience not only to the work in particular but also to the various authorities regulating the traffic in the London streets without in any material degree affecting the traffic of the river itself.

In 1887 an Act for the Extension to Stockwell was obtained, and later Acts sanctioned the line to Clapham Common, the Angel and Euston. It is generally admitted that the internal diameter of the tunnels, which is 10 ft. 2 in. on the original line, and at other parts not more than 10 ft. 6 in., is too small to deal with London traffic, and, as you are no doubt aware, these tunnels are now being enlarged throughout, so that the standard rolling stock of the London Electric Railway Company can be run through from the Hampstead and Highgate lines when the new deviation railways between Camden Town and Euston have been constructed, and which are now being actively proceeded with.

The station tunnels on the original section of the City & South London Railway were built of brick in the old-fashioned way, as shewn in the figure 1 of the Oval Station. The tunnels between the stations, and the station tunnels are not always placed at the same level. Regents Park Station on the Bakerloo is a case in which it was necessary to put the station tunnels at different levels so as to permit of a proposed junction being made with a railway which was at one time intended to be constructed between Regents Park and Euston. At South Kensington the station tunnels had to be placed at different levels as there was not sufficient room between the public road on one side and the Metropolitan Railway Company's boundary on the

other to enable the tunnels to be placed in the most convenient manner, namely at the same level, as is generally done.

On the opening of the first section of the City & South London Railway in 1890 it was realised that Greathead's methods could be applied at comparatively small cost to the construction of deep level tube lines placed in the thick stratum of clay which underlies the greater part of London. The year 1892 accordingly witnessed the first of a number of separate and independent schemes for Tubes and in 1893 the following were authorised :

Central London Railway (Shepherds Bush to Bank) : 6 1/2 miles;

Waterloo & City Railway : 1 1/2 miles;

Great Northern & City Railway (Finsbury Park to Moorgate Street) : 3 miles;

City & South London Extension to Islington : 3 miles;

Charing Cross & Hampstead : 5 miles;

Baker Street & Waterloo : 3 miles.

There are now open in London for public traffic over 44 miles of double tube railway. (See fig. 2.)

With the exception of the Waterloo & City Railway, which was constructed under the auspices of the London & South Western Railway, the whole of the railways had, as already stated, been promoted as independent and separate undertakings. It is largely owing to this fact, and the glorious isolation that each Company hoped to enjoy, that the interchange stations such as at Oxford Circus and Tottenham Court Road, and at other points, have been so badly arranged from the point of view of the convenience of traffic, and there is no doubt in my mind whatever that the early promoters succeeded eminently in isolating their own systems and not recognising the great advantages that would accrue from interchange of traffic.

Before a tube railway can be made a good deal of preliminary work has to be done. In the first place (I am now talking of the original lines), an Engineer would work out the route along which a railway should be constructed. He would then generally get into touch with some well known firm of Solicitors, who would obtain the assistance of a number of influential men in the City with a view to promoting what is termed a Railway Bill, asking for Parliamentary authority for the construction of the proposed line. The promoters would then obtain the services of a Land Valuer who would recommend what properties (if any) should be acquired for the stations, and the Engineer would then work out plans and estimates for the scheme, while the Solicitor would prepare the details of the Bill, with a Book of Reference in which are recorded the names of all property owners, lessees, and occupiers along the line of route within the areas scheduled for the proposed work. When the plans have been deposited in the Parliamentary Bill Office, together with the Bill, and the necessary advertisements have been placed in the public papers with regard to the scheme, the plans are examined by the Examiner of Standing Orders to see if they comply with the requirements of Parliament. If they do, the Bill is next sent to a Committee of the House of Commons when evidence is taken for and against it on its merits, and if it passes the Commons Committee it has to go through a similar ordeal before a Committee of the House of Lords. It is the duty of the Engineer to place all the facts about the scheme before the Committees and prove the estimates as regards their accuracy, and he is often in a very unenviable position when under cross examination by some of the most brilliant Parliamentary Barristers in the country.

During the hearing of the arguments for and against the Bill any of the public who have petitioned against it can then appear and state their objections, and if possible obtain special clauses for their protection.

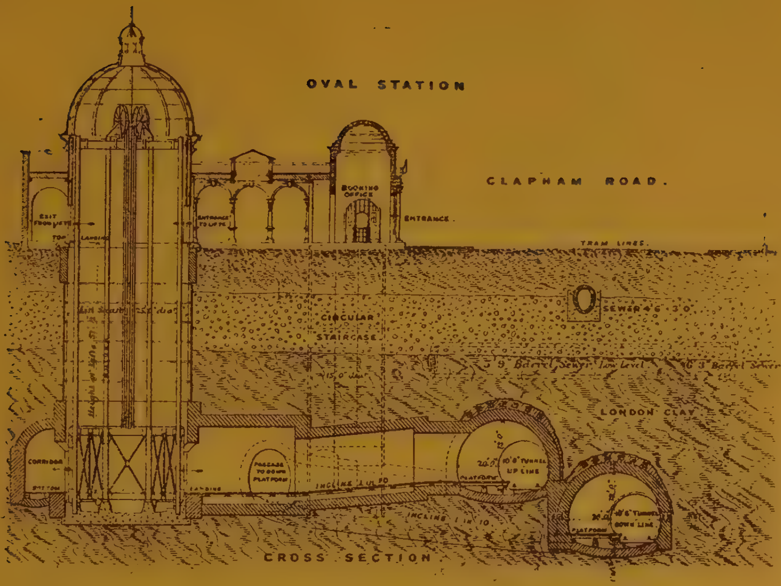

OVAL STATION
CLAPHAM ROAD.
BOOKING OFFICE
ENTRANCE.
TRAM LINES.
CIRCULAR STAIRCASE
SEWER 4'6" 3'0"
LONDON CLAY
CORRIDOR
PASSAGE TO DOWN PLATFORM
10'6" TUNNEL UP LINE
PLATFORM
INCLINE 1 IN 10
CROSS SECTION

Fig. 1.

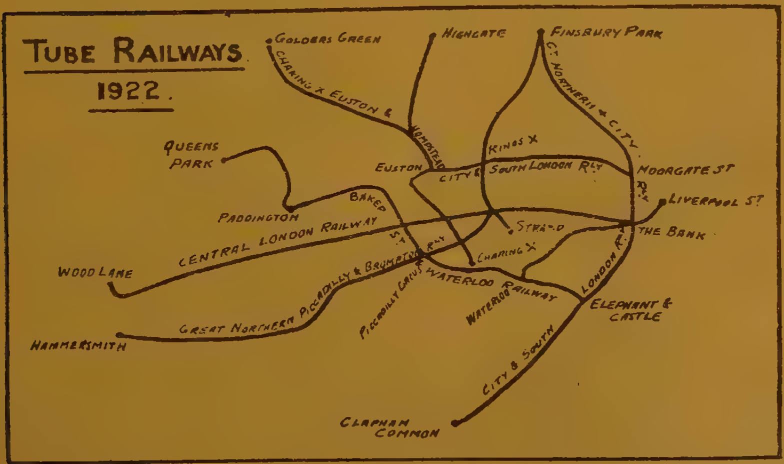

TUBE RAILWAYS
1922.
GOLDERS GREEN
HIGHGATE
FINSBURY PARK
CHARING X EUSTON &
HAMPSTEAD
GT NORTHERN & CITY.
QUEENS PARK
KINGS X
EUSTON
CITY & SOUTH LONDON RLY
MOORGATE ST
LIVERPOOL ST
BAKER ST.
PADDINGTON
CENTRAL LONDON RAILWAY
STRAND
THE BANK
CHARING X
WOOD LANE
PICCADILLY & BROMPTON RLY
WATERLOO RAILWAY
PICCADILLY CIRCUS
WATERLOO
LONDON B.
ELEPHANT & CASTLE
GREAT NORTHERN PICCADILLY
HAMMERSMITH
CITY & SOUTH
CLAPHAM COMMON

Fig. 2.

If the Bill passes successfully through both Committees it is reported to the House and eventually becomes an Act. The Company is then authorised to raise the necessary money from the public and construct the railway.

The Engineer is then given instructions to prepare careful surveys of the route, take whatever borings are necessary to determine the nature of the ground in which the tunnels are to be constructed, and prepare working drawings and contract quantities with specifications describing exactly how each part of the work is to be done.

Responsible firms of contractors are asked to submit tenders stating what would be the cost of the work if carried out by them in accordance with the contract plans and specification.

As soon as the contract has been let to one or more contractors the works are started at various points, the lift shafts at several of the stations being used as working shafts from which the tunnels are to be driven, the shields from one station being driven to meet those coming from an adjacent working site. Some very accurate work has been done by the young engineers whose duty it is to set out the position of the work underground and give directions to the men who are working the shields, the tunnels in some cases being not more than 1/8 inch out from their true position, and if there is more than 1/2 inch of error the setting out is considered to be not well done.

Gradients.

A peculiar feature in connection with the London Tube Railways, and one which tends to great economy in the cost of operation, is the method used where possible of so grading the tubes that between the stations there may be a dip or depression, each station being as it were on a summit. To show that there is nothing new in this idea, it may be mentioned that so long ago as the year 1833 a model of a spring locomotive and a short length of track with gradients dipping between the stations, was made by some persons interested in railway construction, and a large number of the shareholders of the London & Birmingham Railway (now the London & North Western Railway) petitioned the Directors to stop the construction of that railway and also to proceed with the section between Birmingham and Liverpool on the principle of dipping gradients. They maintained that the experimental spring locomotive had demonstrated that, as compared with a level line, a railway with dipping gradients enabled the journey to be done in two thirds of the time for the same expenditure of power.

This of course is true only if there be a station at each summit at which the train has to stop, so nothing came of the proposal until Greathead first applied this principle as far as possible on the original section of the City & South London Railway.

In all tube lines subsequently built, particularly in the case of the Central London Railway, which is more or less level throughout, this principle has been observed where practicable.

The section of tube railway which has the steepest gradients against the load of any in London is that of the Bakerloo Tube between Kilburn Park and Queens Park Stations, where there is a gradient of 1 in 48 for a distance of about 2 000 feet. In the case of the Piccadilly Tube between Earls Court and Barons Court there is a gradient of 1 in 50 for 2 213 feet; but the Hampstead Tube has a much longer gradient of 1 in 60 for 4 333 feet between Hampstead and North End Stations.

There is a rise between the rails under the river at Charing Cross on the Hampstead Tube and the mouth of the tunnel at Golders Green of 282 feet, and from the river to Highgate Station of 151 feet.

On the Bakerloo Railway the rails of the Elephant and Castle Station, which are the lowest down of any in London, are 79 feet below high water in the river. There is a rise between the Elephant and Castle and Queens Park Station of 172 feet. In the case of the Piccadilly Railway the portion between Earls Court and Holborn is more or less on an even gradient; but between Finsbury Park and Holborn there is a fall of 136 ft. 6 in. and between Holborn and Hammersmith Stations a total rise of 62 feet. The Hampstead Tube has the deepest lift of any on the lines in London, those at Hampstead station being 181 ft. 4 in. below the street; and the depth of the tunnels below the surface of the ground near the White Stone Pond is 250 feet.

The Hampstead Tube as originally designed by Greathead started at Craven Street alongside the South Eastern Railway Company's Charing Cross Station, and followed the existing route as far as Hampstead Heath Street, which was the original terminus proposed for the line. On the Highgate branch the railway was proposed to terminate at Kentish Town.

Between Chalk Farm and Hampstead the railway was laid out by Greathead at a much higher level than that at which it has been constructed; in fact his original idea was to introduce gradients of 1 in 24 and work the railway by cable traction, and when necessary wind out the trains into a repair yard a Heath Street in the same way as was originally proposed in the case of the South London Railway at Stockwell.

It may be of interest to you, and worth recording as an historical fact, that when the late Mr. Yerkes was negotiating for the construction of the London Tubes, he sent a Mr. Lauderback as his agent to investigate the question of London traffic, and one day I had a telephone message from the Hotel Cecil where Mr. Lauderback was staying to go and see him the following morning at 10 o'clock with a view of taking him over the route of the proposed Hampstead Tube. This was before the days of motor cars and we accordingly got into a two-horse conveyance at the Hotel Cecil and went all the way up to Hampstead. During my journey with Mr. Lauderback I decribed to him as well as I could the general scheme for the railway; but when I informed him that the idea was to work it by cable on gradients of 1 in 24 between Chalk Farm and Hampstead, and that the railway was to terminate at the top of the hill in Heath Street he looked very unhappy and said to me that the scheme was no good at all, and unless the railway could be extended out to the open country he was going back to America to tell Mr. Yerkes the proposition was not a sound one. I thought therefore the best thing to do was to go on out towards Golders Green and we drove past Jack Straws Castle and the Bull Inn down the North End Road to Golders Green Cross Roads. When we got there Mr. Lauderback turned round to me and said, « This is where you should bring your railway to, and unless you do this it is no good. I pointed out to him that there were no houses, there were no people, and there were only open fields at Golders Green; and he said that did not matter a bit as in America they made the railways first and the people naturally followed afterwards.

I must confess at the time I thought Mr. Lauderback was quite wrong and that his idea seemed rather a harebrained one; but as matters have turned out I was wrong and Mr. Lauderback was quite right.

That, however, did not settle the business. I set to and worked out a scheme for the line to be laid out to Golders Green on its present route. Mr. Yerkes subsequently came over to this country to go into the whole business himself, it having been decided to get Parliamentary powers to extend the line from its then authorised terminus at Heath Street, Hampstead, to Golders Green.

It may further interest you to know how Mr. Yerkes made up his mind that he would make the railway. It seems he went with his Agent, a Mr. Davis, from his London hotel on a very wet day over the route of the railway. It was raining all the way until the carriage got on to the Spaniards Road opposite Heath House, when, as Mr. Davis informed me subsequently, Mr. Yerkes stepped out of the carriage; the sun shot out from behind the clouds and illuminated the church spires and towers of London below. Mr. Yerkes turned round to Mr. Davis and said, « Where's London? » Davis pointing in the direction of St. Paul's said, « There it is. » Upon which Mr. Yerkes turned round and said « Davis, I'll make this railway », and got into the carriage and drove back. He evidently had been much impressed with the view.

Tunnelling.

A number of different methods of tunnelling were necessary in various parts of London according to the nature of the ground met with in each case. For instance, although the bulk of the tunnelling has been executed in the London clay, water bearing gravels and sands were encountered at certain parts of the railways. Where the tunnels are in the London clay the Greathead shield has principally been employed, and another type of machine called a rotary shield has in certain parts been adopted by different contractors with the idea of employing fewer men and doing the work more rapidly. For short lengths of tunnel and for the construction of station passages the work has invariably been done without the use of a shield, by the ordinary methods of mining.

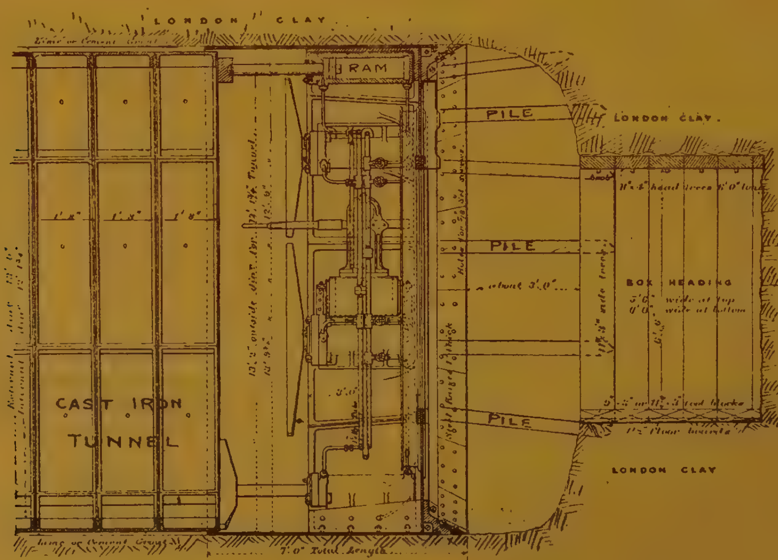


Fig. 3.

The Greathead system of tunnelling in the clay consists of driving a heading by hand labour in front of a shield as shewn in figure 3 and utilising for the purposes of excavation the hydraulic power by which the shield is propelled so that

in advancing it causes the face of the excavation to be broken up by the interposition of a series of short timber piles placed between the shield and the ground, the material so dislodged being removed by hand labour after the shield has come to rest.

Owing to the extremely limited space in front of the shield, namely about 15 inches, it is not possible for more than one, or at the most two miners, to work at one time. Consequently, to get space for more men to work, the timber heading shewn in the slide is always driven forward with the work while the advancing shield shortens the heading at its rear end.

In order to utilise the pressure of the rams to the fullest extent for the purpose of breaking up the ground at the face the timber piles already referred to are placed round the entire circumference of the bullhead casting slanting slightly upwards. When all is ready the two nearest supports of the heading nearest to the shield are removed, or in some cases only slackened so as to allow the face to collapse towards it. The instant the hydraulic pressure is applied to the rams the shield advances slowly causing the piles to penetrate the face and so detach from it large lumps of clay. In this manner the material is completely broken up by the piles and falls into the length directly in front of the shield. It is subsequently removed by the miners and cast on to the stage at the back of the shield and then shovelled into skips for removal, either by small ponies or by electric locomotives.

The maximum speed of advance is generally about 10 feet a day of 24 hours in the case of the small tunnels between the stations. The large station tunnels which are also built with shields of special design, are generally constructed at a speed of about 6 feet per day. The iron segments of the small tunnels are lifted by hand and bolted together in position, but in the case of the large station tunnels, owing to the greater weight of the castings, special hydraulic erectors are fixed to the shield and are used to lift and put in position the several segments forming a ring of iron.

On the original sections of the City & South London Railway the station tunnels were built of brickwork in the old fashioned way, but during the construction of the Waterloo & City Railway, of which I was Resident Engineer, Greathead proposed that the station tunnels in the City of that railway should be formed of cast iron segments and constructed by means of shields. This method of construction is now universally adopted for the station tunnels, as under the old system of brick tunnel construction there is great danger of subsidence of the ground.

Where a shield is used it is about 1 1/2 inches larger all round than the outside of the tunnel, and overlaps the forward portion of the completed tunnel. There is therefore an annular space about 1 1/2 inches wide left round the tunnel when the shield moves forward, and if this space were not solidly filled in while the tunnel was being constructed subsidence of the ground would take place, buildings overhead would be cracked, and considerable injury result.

This space is filled in with what is called grout. Grout consists of fresh hydraulic lime mixed with water, or Portland cement mixed with water, and these materials have the property of setting hard very quickly.

The operation of grouting is a very important part of the system of tunnelling originated by Greathead. The apparatus which he invented for this purpose is called a grouting pan and is shewn on the next slide, where it will be seen a flexible hosepipe passes between the pan and the tunnel lining. The pan itself is filled with cement and water, which are thoroughly mixed by turning the handle shewn at one end of the picture. Compressed air brought

down a pipe from the surface is then let into the pan at a pressure of about 60 lb. per square inch, and when the hosepipe has been connected to the tunnel by placing the end of the gun in a hole in the casting, the grouting valve on the pan is opened and the compressed air then forces the liquid grout out of the pan, along the hosepipe, and into the annular space between the tunnel and the ground, and completely fills up the space. Within a few hours the grout sets quite hard and supports the ground on the top.

This apparatus is a great improvement on the original methoh which Greathead used when constructing the Tower Subway, where he mixed the lime grout in an ordinary bucket and after filling a garden syringe with the mixture, which was purposely made very liquid, squirted it through holes in the tunnel segments so as to fill the space outside.

During the construction of the Central London Railway two types of mechanical excavators were tried with indifferent results; one in the form of a ladder dredger, and the other as a rotary excavator.

An improved form of rotary machine was used on the Hampstead and Piccadilly Tubes, and with it some excellent work was done.

Some little difficulty was first experienced in steering the machines and keeping them on their true line, but when they had been equipped with some guiding rods and the men became accustomed to their use, the work proceeded rapidly and accurately.

Under favourable conditions the rotary machine progresses much faster than the Greathead shield, the superiority in this respect being noticeable in extremely hard clay, which offered excessive resistance to the cutting edge of the Greathed machine but was pared away with comparative ease by the rotary machine. On the other hand, in some kinds of ground the Greathead machine works better, and on the score of accurate alignment and freedom from subsidence proves more satisfactory.

There is one objection to the use of a rotary machine which has not yet been got over, and that is that owing to the much greater length of tunnel, from 20 to 25 feet per day, that can be constructed by it, the cement grout which is forced into the annular space outside the tunnel does not set sufficiently rapidly to give adequate support to the ground, and on that account there is under certain conditions considerable fear of subsidence and damage to property overhead if the tunnels are constructed too rapidly.

The above remarks with regard to tunnelling refer to tunnels constructed in the London clay. I now propose to tell you as shortly as possible how tunnels are made under the most difficult conditions, namely through water bearing strata such as gravel and sand. Under these conditions compressed air is used primarily to exclude water which would otherwise enter the workings and have to be removed by continuous pumping, as Brunel did when he made the Thames Tunnel. The employment of compressed air as an aid to underground mining operations and shaft sinking was first suggested by the famous British Admiral Sir Thomas Cochrane, afterwards Lord Dundonald. In 1830, that is while Brunel was hard at work making the Thames Tunnel, Cochrane took out a patent for an apparatus for maintaining high pressure air at the working face of the tunnel. This apparatus included air locks through which men and materials could pass from the ordinary air into compressed air and vice versa.

An airlock as now applied to tunnels consists generally of a steel boiler about 5 ft. 6 in. in diameter and 13 feet long built through a brick or concrete diaphragm wall closing the tunnel at a convenient point before water is encountered. This airlock has two doors, an outer and an inner door, both open-

ing in the direction in which the tunnel is intended to be driven, and one of which is always closed.

When compressed air is applied to the workings the inner door, that is that nearest to the working face, is first shut tightly against an indiarubber joint which air cannot pass. The compressed air is furnished by a compressor or compressors at the surface through a pipe about 8 inches in diameter carried through the diaphragm wall to one side of the lock. It has a hanging valve placed at its extreme end which projects some distance into the tunnel.

The face of the workings being impervious, the air in the tunnel between the airlock and the working face gradually becomes compressed as the engine forces air down the shaft and through the air delivery pipe into the tunnel.

We will assume that a person is about to enter the lock in which the air stands at the same high pressure as in the part of the tunnel beyond the wall. He signals for the farther door to be shut, and then turns a valve by which the air inside the lock escapes till it attains atmospheric pressure. Then he enters, closes the valve and door carefully and turns a cock admitting compressed air from the tunnel into the lock. At this period most novices experience a curious sensation of pressure in the ears, followed by pain and bleeding at the nose and ears, which renders a retreat advisable for the time. Discomfort is reduced by sucking a sweet to cause free salivation, and by swallowing frequently.

When the pressure inside the air lock has risen to that in the tunnel the inner door is pushed open easily, while the outer door is kept tightly closed by the full pressure that is acting upon it. To come out from the workings through a lock, the procedure is reversed, the air inside being allowed to escape gradually until the outer door can be opened.

Anyone who has had experience of river locks will understand that the principle on which they work is similar to the compressed air-lock in all respects, the level of the water in the one case corresponding to the air pressure in the other.

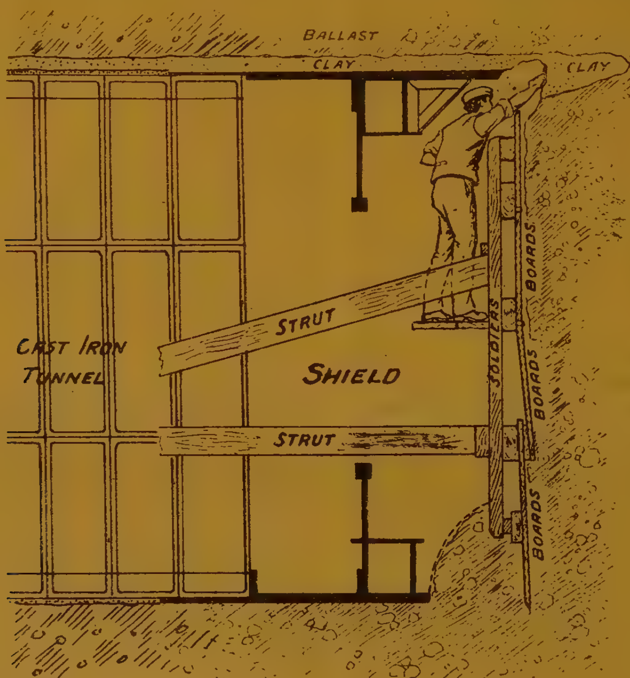
Before a person can enter or leave an airlock or water lock the air or water conditions must be the same inside the lock and on the side from which or to which he wishes to go.

Referring now to the actual methods adopted for tunnelling in water bearing strata, where it is imperative that no subsidence of the ground should take place, there are two methods by which the work is carried out; one known as the assisted shield method, and the other as the hooded shield and clay pocket system which was first brought into use during the construction of the Waterloo & City Railway.

The assisted shield method is that which up to a few years ago was universally adopted as the only method possible of constructing a tunnel *without causing subsidence of the ground overhead,* with of course consequent damage to buildings. It was the system which Greathead carried out when constructing the tunnels through waterbearing strata under Clapham Road and other parts of the South London Railway. Both systems require the application of compressed air to the workings to blow back and thus keep water from entering the tunnels while the work is in progress, and under Greathead's assisted shield method, in order to enable the shield to advance and the tunnel to be constructed under cover of the machine, the ground is mined in advance of the apparatus, in front of the shield boards are placed so as to support the ground in advance of and before the shield can be moved forward. The boards are accordingly buried outside the shield and outside the tunnel, the space between the tunnel and the boards being grouted so as to thoroughly support the ground.

When the boards are being put in position one by one there is a very large loss of compressed air in the face which of course has to be made good by the air compressing machinery at the surface, and this system is not altogether free from danger to the men as the ground must be excavated before it can be supported by the timber boards, and if the pressure of the air in the tunnel is not sufficient a bad run of ground may take place and block the tunnel up and bury the men.

When I was in charge of the Waterloo & City Railway construction work this mode of working was adopted under



THE HOODED SHIELD AND CLAY-POCKET SYSTEM OF TUNNELLING THROUGH WATER-BEARING STRATA.

Fig. 4.

Mr. Greathead's advice for the tunnels driven under Stamford Street where there is a great deal of sand and gravel, with a head of about 20 feet of water. It was during my experience on this work that it occurred to me that a safer, simpler and cheaper system could be devised, and I accordingly proposed an entirely different method of construction which did not require any timber to be buried outside the tunnel and enabled the work to be done with a greater economy of air. The shield I designed for this purpose is shewn on figure 4.

It is provided with what is termed a hood in front, that is the upper part and sides of the machine project about two

feet or so in advance of the cutting edge at the bottom. My idea was that the miners should form small holes about 2 feet long and 12 inches wide and deep at the upper part of the shield, where you will see in the figure a man is engaged filling in some clay, in order to stop the rush of air that takes place when the hole is actually being formed; and also for the purpose of forming an artificial lining into which the cutting edge of the shield can easily be pushed.

Having formed one hole in that position, another one is formed on either side, each in turn being filled with tempered clay generally called puddled clay. In this manner, hole by hole, a ring of tempered clay is deposited in the ground in front of the cutting edge of the shield. You will notice on the slide the clay is put in above the level of the shield so that when the shield moves forward there is a layer of tempered clay left behind, that is outside the shield, and in that position it has a very important duty to perform in keeping the air from escaping from the tunnel into the ground.

The shield having moved forward so that the cutting edge is completely buried in the clay, the face boards under cover of the hood of the shield are set forward 20 inches, which corresponds to the length of ring of tunnel iron. A new ring of tunnel iron is then built under cover of the tail of the shield and the space between the previous ring and the tempered clay now exposed is filled with cement grout.

Another set of pot-holes is then made and filled with clay and the shield pushed forward for a new ring of tunnel iron which is then erected. The grouting again is proceeded with and so the work advances ring by ring. You will notice when the shield moves forward the ground over the tail of the shield of course loses its support, but owing to the fact that the tempered clay was put in at such a level that a layer of clay is always left outside the shield, the clay in that position forms an impervious stratum so that the compressed air is locked into the tunnel and cannot escape through the clay. The compressed air accordingly does the very important work by its elastic reaction of holding up the ground until the annular space outside the tunnel lining has been grouted.

When I first proposed this system it was strenuously objected to by the men who said it could not be done with safety, as at that time we had about 20 feet of water over the tunnel; but to prove the fallacy of their arguments I myself made the first pot-hole in February 1896 in the experimental shield we put up when tunnelling under Stamford Street on the Waterloo & City Railway, and was able to make a pot-hole 3 feet in advance of the shield with the greatest ease, although, as a matter of fact we only wanted the holes to be 23 inches long; and so demonstrated to the miners who came into the shield with me to see the experiment, that their fears were entirely unfounded.

Since then the mining community have taken very kindly to the system as they can now arrange for doing the work at piecework rates, which they so much love.

It was under this system that both tunnels of the Bakerloo Railway under the Thames at Charing Cross were driven through the open gravel with a maximum head of 70 feet of water at high tide, the work being carried on at times under a pressure of 30 lb. per square inch, with the greatest regularity, which is one of the essentials in economical tunnel construction.

For weeks together these tunnels were constructed at a speed of 5 feet per day of 24 hours.

The shield we used for the river tunnels at Charing Cross just referred to was provided with a special apparatus originally proposed by Greathead, called a

trap or water seal, which in the event of a mishap, such as an inflow of material at the face blocks the further movement of the ground and saves the tunnel from being completely filled up with the inflowing material if the compressed air is not able to blow the water back.

Although by this system of tunnelling the air losses are much less than in any other system that has yet been tried, still the losses at times are very great.

Escalators.

As you are aware, owing to the considerable depth below the surface at which most of the Tube lines have been constructed, lifts have been provided for giving access to and egress from the railways. On the South London line as originally planned by Greathead the lifts are worked by hydraulic power, but in the extensions of that railway and the other tube lines of the Underground group the lifts are worked electrically.

It was not until the year 1911 that escalators were introduced on the Underground system at the suggestion of Lord Ashfield, then Mr. Albert Stanley. He then sent for me and instructed me to prepare a design for escalators at Earls Court to form an interchange between the District Railway and the Piccadilly Tube.

This is the first case of the adoption of escalators for Tube Railway work in England. Shortly after this I received instructions to design escalator approaches for the stations on the Extension from Paddington to Queens Park, as well as for the interchange between the Bakerloo and Hampstead Tubes and the District Railway at Charing Cross.

The escalators at Charing Cross, was a very complicated piece of work to design and in parts very dangerous to carry out; in fact we had to construct a passage, the top of which was only about 4 feet below the clay, and form it across the Bakerloo Station tunnels at the Embankment Station. For this purpose it was necessary to use compressed air, as we had about 17 feet of water overlying the clay. We therefore applied compressed air to the work and drove the passage over the two tunnels without disturbing the grout which had previously been put in, so that the air pressure did not escape into the station tunnel in which the trains were running at the time.

This work was carried out by Messrs. Mowlem, the Contractors, with the greatest success.

On the Queens Park Extension, Lord Ashfield was anxious to combine the escalators and the dead staircase in one tunnel, and this idea which I worked out was his suggestion; but it involves the idea of a tunnel of the same size as an ordinary station tunnel which contains a platform and one line of rails.

One of the most interesting stations where escalators have been put in is at Oxford Circus on the Bakerloo Tube, where the Bakerloo & Central London Railways cross each other, the top of the Central London Railway tunnels being 6 inches below the bottom of the Bakerloo Tube under the Circus. There is a large sewer close above the Bakerloo station tunnels at that point, and we had to construct the Bakerloo Railway between the Central London Railway and the bottom of the sewer, and had in fact only a very few inches to play with.

Figure 5 shews the original lay-out of the passages between the bottom of the lift shaft and the station platforms of the Bakerloo and Central London Railways at Oxford Circus Station. As most of you know, passengers have a very considerable distance to walk between the bottom of the old lift shaft and the platforms of the Bakerloo Tube. It therefore became fairly easy to arrange for escalators to deal with the traffic as we had the necessary length between

the surface station and the platform tunnels for the escalator to be constructed. This escalator has a rise of 54 feet and is the deepest we have in London.

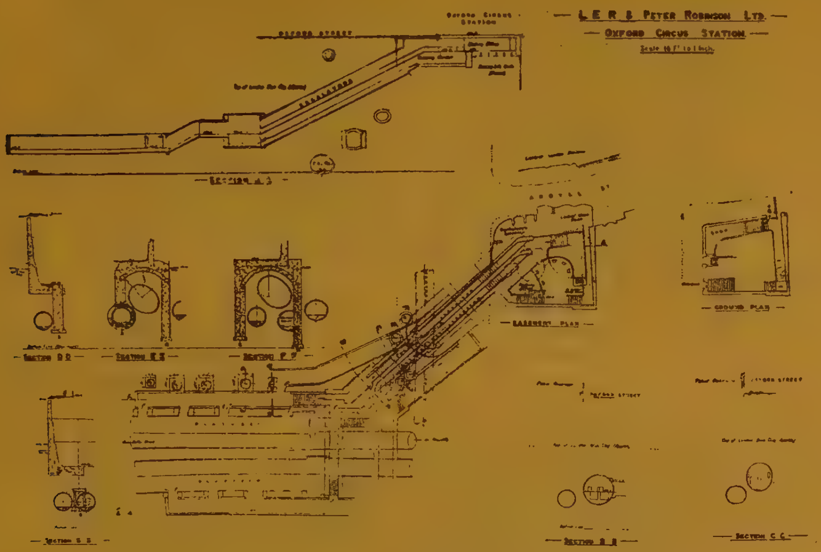


Fig. 5.

Recently we have had to put some additional strengthening works round the tunnel at this station owing to the reconstruction by Messrs. Peter Robinson of their new premises at the North East corner of the Circus, and in order to take the load of their building off the tunnels it has been necessary to carry out some very extensive underpinning work for the protection of the railway.

[669 .1]

Malleable cast iron,

By E. TOUCEDA,
CONSULTING ENGINEER, AMERICAN MALLEABLE CASTINGS ASSOCIATION.

Figs. 1 to 7, pp. 469 to 475.

(*American Machinist.*)

A non-technical article descriptive of any foundry product, in order to prove of real practical value to the general reader, must cover quite completely the details concerning the physical and structural characteristics of the product, the ease with which it can be machined, the facility with which it can be hot or

cold worked, heat-treated or welded, and its cost. The commercial worth of any industrial product is determined not only by a consideration of these various characteristics, but by a rigid comparison of these properties with those possessed by such products as could be commercially substituted for it.

There are reasons, however, why it will best serve our purpose to consider first what these properties may be in the case of pure iron if it is used as a casting material. With this data in hand, and with some essential preliminary explanations, the reader will be in a position to exercise his own judgment in sizing up the advantages or shortcomings of the malleable iron casting as compared with the products that might be used commercially in its stead. He will be in a position as well to gather an intelligent idea as to the field to which this casting is best adapted.

According to various authorities, pure iron has an average ultimate strength of about 50 000 lb. per square-inch, accompanied by an exceedingly high ductility. Owing to the absence of carbon or phosphorus, the two elements that impart fluidity, this metal is extremely sluggish when molten. Structurally, pure iron when cast is made up of an aggregate of coarsely crystalline grains, as the microphotograph in figure 1 shows. While these grains are typical in form, their size will depend upon the rate of cooling from solidification. Therefore, it follows that if two castings of equal length but of different sized sections are poured from a ladle of pure molten iron, the crystalline structure of the heavier casting will be larger than that of the lighter, in proportion to the disparity in section.

As it is in rare cases only that castings are designed with uniform sections throughout, it follows that the crystalline structure of the thicker sections will be larger than that of the thinner sections, owing to the fact that the thicker sections cool more slowly than do the thinner ones. Not only is a coarsely crystalline structure unreliable in service, but internal strains are unavoidably developed in the casting, occasioned by the difference in the rate of cooling of the heavy and light sections. These strains are frequently of such magnitude as to cause the casting to crack either when cooling or when subjected to any slight strain in service. The more uneven this structural state is, the greater is the probability that these troubles will occur.

Experience has shown that if such a casting as we have just described is placed in an annealing oven and heated to around 900° C. for a short interval of time and then slowly cooled, the defects in the structure will be modified. Not only will the coarsely crystalline grains in both the thick and thin sections be changed into ones very minute and uniform in size throughout all sections, but the internal strains which were occasioned by the difference in the rate of cooling of the disproportionate parts, will be removed.

Without entering into complete details, it can be stated that in the case of all of the various ferrous products to which we will refer, there exists a certain temperature at which the metal ceases to be magnetic. The constitutents that exist and are stable below this temperature change into others wholly different and stable only while above it. A coarsely crystalline structure can be broken up and replaced by one that will be permanent, very minute, and most reliable for the particular product in question.

In spite of what has been stated, castings of pure iron cannot be produced successfully or commercially for either structural purposes or for the construction of machines. On the one hand, they would be prohibitory in cost, while on the other, even if they were cheap, the lack of fluidity of pure iron when molten would occasion high loss due to

Fig. 1. — Microphotograph of pure cast iron, showing the coarse crystalline grains.

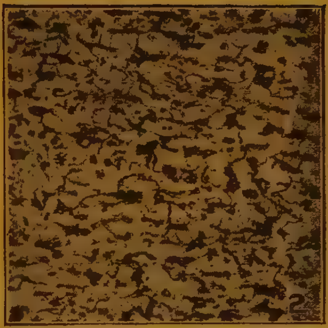


Fig. 2. — Microphotograph of steel containing 0.12 °/₀ carbon, showing the carbonless iron and pearlite.

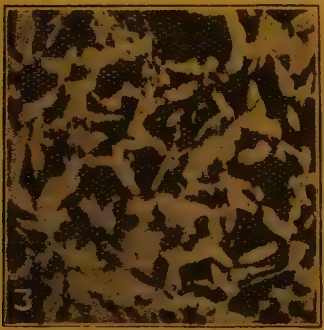


Fig. 3. — Microphotograph of steel containing 0.34 °/₀ carbon.

Fig. 4. — Microphotograph of hard iron, showing carbide of pear lite.

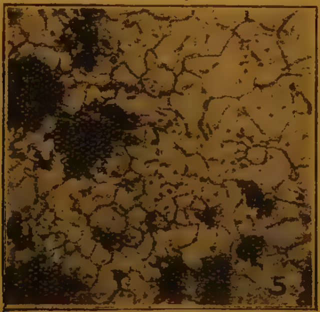


Fig. 5. — Microphotograph of malleable cast iron after annealing.

mis-runs. The contraction after solidification is so great that any casting of intricate design would crack and pull apart at the junction of the thick and thin sections. A further handicap would lie in its high melting point, to which must be added several hundred degrees of superheat in order to raise the metal to a proper casting temperature.

Poor machineability, a characteristic of all soft metals such as copper and aluminum, is another shortcoming of pure cast iron. The castings would be unsound due to the blowholes which are very pronounced for such sluggish metals. The welding properties of such material are the best of any ferrous product, while it can be hot or cold worked with the greatest facility. The foregoing has been entered into in order to explain certain facts that could be more clearly brought out by a consideration of the characteristics of this metal whose casting properties could hardly be worse.

The main difference between pure iron and steel is that the latter must contain at least some carbon in order that it can be thus classified. The effect of adding carbon to pure iron manifests itself in an increased tensile strength, a lessened ductility and an increased hardness, each in proportion to the amount of carbon added. The reason for these results lies in the fact that carbon does not remain as such when added to molten iron. As soon as carbon is added, it combines chemically with about fifteen times its weight of iron to form an intensely hard compound of definite composition called « carbide of iron »; and this notwithstanding the fact that one constituent is very soft and the other comparatively so.

But it happens that, some time after the metal has solidified, this very hard carbide of iron refuses to remain by itself and gathers unto and attaches to itself about eight times its weight of iron. As a result a mechanical mixture of definite composition is built up through the union of the two. A distinct constituent is created, which, while not quite as hard as carbide of iron, is much stronger and more ductile, although it is less ductile than pure iron.

It should now be plain to the reader why an exceedingly small amount of carbon added to pure iron can have such a profound effect on the physical characteristics of the latter. This can be illustrated by the use of concrete figures. If to pure iron such a trivial amount of carbon as 0.1 % be added, two reactions will take place. First, there will be formed from this 0.1 % of carbon about 3 % of iron carbide. Second, after solidification and at about redness, this 3 % of iron carbide will unite with about 8 times its weight of iron to form about 12.5 % of the mechanical mixture known as « pearlite ». In figure 2 is shown a microphotograph of steel containing about 0.12 % carbon. The white areas are the carbonless iron and the dark areas the pearlite. Figure 3 shows a microphotograph of the structure of a steel which has a 0.34 % carbon content.

Not only does carbon when introduced into pure iron produce the far reaching effects noted, but it also has a marked influence on the melting point of the metal and on its fluidity and contraction. This is the case to such an extent that very superior castings could be made of this very pure steel, which would have a strength, ductility and hardness very easily adjusted by the carbon content. However, it happens that commercially, castings cannot be made of pure iron and carbon, because of the great expense that this would entail.

Commercial steel is always contaminated with a greater or less percentage of phosphorus, sulphur, manganese and silicon, the first two being very harmful when in excess of a certain quantity. Consequently, its freedom from the first two chemicals is a measure of the qua-

lity of commercial steel. Its carbon content, owing to its influence on the physical characteristics of the metal, actually determines its appropriateness for this or that particular purpose. For this reason carbon is not considered in the light of an impurity, but as a blessing.

The American Society for Testing Materials grades steel castings into class *A* and class *B*. With reference to those of class *A* which, the writer can state, predominate by a considerable amount in tonnage, it is provided that they need not be annealed unless so specified. While no physical requirements have to be complied with, it is required that the carbon and the phosphorus should not exceed 0.30 % and 0.06 %, respectively.

In the case of class *B* castings, it is provided that in all cases they shall be properly annealed, depending upon their design and composition. This class is graded into soft, medium and hard, having, respectively, minimum ultimate strengths of 60 000, 70 000 and 80 000 lb. per square inch. The yield point in each case should be at least 45 % of the ultimate strength. The elongations should not be less than 22 %, 18 % and 15 %, while the reductions of area should not be less than 30 %, 25 % and 20 %, respectively. In regard to composition, it is specified that both the phosphorus and the sulphur content must be less than 0.05 %.

No better casting exists than a sound, high-grade steel casting, and the remarks that follow are not intended to offset or negative this statement in any particular. All products have certain properties that make them superior to others, while on the other hand they have other characteristics that would make the reverse statement equally true.

It has been pointed out that class *A* castings predominate in tonnage and that they do not need to be annealed unless so specified. It can be stated then that, with this privilege allowed, not all such castings receive annealing treatment. It has been pointed out also that under these conditions the crystallization must be coarse in proportion to the size of the sections, as well as different in size in disproportionate sections, while internal strains must be present for reasons already explained. In spite of this there is a large sale of class *A* castings, even when they are unannealed.

It has been explained that the hardness of steel is a function of the carbon content. Inasmuch as quantity production is one of the essentials insisted upon by our manufacturers, it will be found that they will purchase in preference a low rather than a high limit of carbon for class *A* castings. Exception is made to this, however, for special parts where high strength is needed, and on this account the ease of machining is sacrificed. This will mean a product that will probably not be higher than 0.15 % in carbon. Even with a carbon content as low as this, these castings will have a machining cost far in excess of what would be necessary in the case of malleable cast iron.

Malleable cast iron is made by melting together a certain proportion of pig iron, sprew and low-carbon scrap of the proper composition. The molten metal is allowed to remain in the furnace under the oxidizing influence of the furnace atmosphere, until a cast test-sprew, when broken, shows a uniformly white fracture free from any particles of graphitic carbon, or, in other words, until all of the carbon in the metal is in chemical combination with the iron. If this condition is reached, and if the molten metal is hot enough to pour the castings without the danger of mis-runs, the furnace is ready to be tapped.

Castings made from such iron are of extreme brittleness and hardness, and except in rare instances where such properties are actually desired, would serve no useful purpose. The structure of this hard iron is made up wholly of the two

very hard constituents, carbide of iron or cementite and the mechanical mixture known as pearlite. This structure has been microphotographed, as shown in figure 4. The white areas that stand in relief are the carbide and the dark areas the pearlite.

Before proceeding let us note other characteristics possessed by this hard iron, the composition of which will average about 0.85 % silicon, about 2.40 % carbon, about 0.18 % phosphorus, 0.07 % sulphur and 0.25 % manganese. We have seen that both carbon and phosphorus, in the order named, impart great fluidity to iron, and that they act as well to lower its melting temperature. The melting point of pure iron is about 1 500° C., and that of steel castings such as can be machined with fair ease for steel, is around 1 460° C. Hard iron of the composition referred to will have a melting range between 1 130 and 1 275°.

From the foregoing we must conclude that this character of metal is one that is much easier and safer to cast than either pure iron or steel, both on account of its greater fluidity and its far lower melting point. It has been shown that the higher the melting range of a ferrous product, the greater will be the amount of gas absorbed. Consequently, the greater will be the danger from the presence of blowholes, not alone due to the larger quantity of gas absorbed, but more particularly to the sluggishness of the metal.

Of all the defects to which castings are prone, the most serious are due to blowholes. On the one hand, it is impossible to ascertain the presence of blowholes except by the destruction of the casting itself. On the other hand, if a considerable amount of machining be done on castings that must be rejected subsequently due to these defects, the monetary loss will be great. In the case of steel, ferro-silicon and aluminium are the alloys generally used to produce soundness.

It can be safely stated that without the addition of some alloy to take care of the occluded gases, the soft steel casting would not be a commercial product. White iron, or hard iron as it is called in the vernacular of the foundry, contains an average of about 0.85 % silicon and 2.45 % carbon as cast. No alloys are ever added for the prevention of blowholes, as hard iron is practically free from this evil. This does not mean that blowholes never exist in the malleable iron casting, for such is possible due to bad molding practice, the blowing of a core or damp sand — accidents that may happen in the case of any cast product. It does mean, however, that only in very rare cases are they ever caused by occluded gas.

It, therefore, can be accepted as a fact that hard iron is essentially a sound metal. The contraction of white iron is not only somewhat less than that of steel, but from the evidence furnished it is clearly a metal of much greater fluidity and of lower melting range. From this, it follows that unsoundness due to shrink is much more liable to occur in the latter than in the former metal. On the other hand, it is only fair to state that, while the presence of shrink is highly objectionable in either product for obvious reasons, if the product is to be machined a shrink will prove more objectionable in malleable cast iron than in steel, for in the former a hard area will always accompany a shrink while in the latter this is not the case.

After the hard iron castings have been cleaned, they are packed in tightly sealed pots in which they are surrounded on all sides with a slightly oxidizing packing. The pots are then placed in an annealing oven, heated to about 850° C., at which temperature they are held for a period of not less than 60 hours. From this temperature they are allowed to cool at a rate that will not exceed about 10° per hour until the temperature of the castings has dropped to about

600° C., after which the rate of cooling can be considerably increased.

It should be noted that the very temperature that is required for annealing the hard iron castings coincides with the temperature at which the grain is refined. A coarsely crystalline malleable iron casting therefore is quite a practical impossibility. What takes place during this annealing and conversion process can be gathered from a comparison of the microphotograph of hard or white iron shown in figure 4 and the microphotograph of the annealed product shown in figure 5.

It has been pointed out that hard iron is made up wholly of two very hard constituents, cementite and pearlite. Now, while this is true, it must not be forgotten that the cementite existing as such, and the cementite in pearlite, consist of the chemical union of very soft carbon and soft iron. During the heat treatment of the castings, the chemical union is disrupted. The carbon is forced to separate out in small rounded nodules, leaving the carbonless iron as a ground mass throughout which these segregated particles of soft carbon are uniformly distributed.

The malleable process therefore consists first in melting a cast-iron mixture in such a manner that the carbon and iron unite to form a very hard and brittle product, and then in subjecting this product to the influence of temperature and time, whereby the hard constituents are forced to break up into the two original soft ones.

As can be seen by a comparison of the accompanying microphotographs, malleable cast iron has a structure unlike either that of pure iron or of steel. Were we to ignore certain facts, we might state that its structure could be likened to that of pure iron if rounded nodules of carbon were uniformly distributed throughout the structure of the latter. We might also state that the structure of a steel casting would be similar to that of pure iron if the particles of pearlite were located at the junction of the grain boundaries. While such indeed might be the hasty conclusion, there are certain essential facts that must be considered before one can obtain the correct point of view.

If to a ladle of pure iron there is added the same amount of silicon, phosphorus, sulphur and manganese as normally exists in malleable cast iron, but no carbon, and if the structure of this metal is compared with that of pure iron, it might be quite impossible to tell which was which from a comparison of their microphotographs. This is because silicon has the property of alloying with iron with such intimacy that even under the highest magnification one cannot be differentiated from the other. It would be impossible to tell the amount of phosphorus used, while the sulphur and manganese having reciprocal attraction, unite together to form a light slag, which, if given the opportunity, will float to the top of the molten metal. If the metal is too sluggish to admit of its escape in this manner, the slag will be entrained in the casting in the form of rounded particles of indefinite shape that can then be seen and identified.

There will be a marked difference however, in the physical properties of pure iron and the pure iron to which these particular impurities have been added. The addition of silicon will facilitate machineability to such an extent that this can take place at high speed. The strength will be increased without an appreciable sacrifice of ductility. The phosphorus will increase the stiffness, facilitate machineability but decrease ductility to some extent. The sulphide of manganese will be inert, unless it is present in a prohibitory amount.

From the foregoing it can be stated that while the structure of pure iron consists wholly of ferrite (carbonless iron), and the ground mass of the malleable iron casting also of ferrite, in that

it is also carbonless iron, the physical properties of these two types of ferrite are wholly different. This distinction is not always made by writers on this subject.

These matters have been entered into in tedious detail, because the writer has been asked so often by even metallurgists of long experience, how it is possible that malleable cast iron consisting of a ground mass of ferrite so closely resembling the structure of pure iron, but weakened by the presence of particles of free carbon distributed throughout it, can have an ultimate strength considerably superior to that of the latter. In addition, many who use these castings fail to understand why they can be machined at such high speed with an almost perfect surface, while the machinability of pure iron, or iron almost pure like high-grade wrought iron, is so poor, and the machined surface so rough.

Malleable cast iron is a product that is very unique in many ways. As has been explained, it is made from a white cast iron that is very fluid when molten, that melts at a temperature slightly lower than grey iron, and that is very sound when cast, each and all of which are characteristics that make for general integrity of product. The castings are not only very tough and strong, but they can be machined at a much higher speed than is possible in the case of any other ferrous product, and they have a machined surface that is smooth and of close texture. These castings cannot be welded and in this particular the soft steel casting is superior. They cannot be improved by heat-treatment.

Lest the reader be confused, it will be explained that malleable cast iron is a product that has the special characteristics of great toughness and of comparatively high strength accompanied by machining properties that can be excelled only by brass or some other non-ferrous alloy. While steel can be heat-treated in such a manner as to make it capable of standing a much higher strength than when in its raw state, this will be at the cost of ductility on the one hand and, to a much greater extent of lessened machineability on the other. Malleable cast iron cannot be thus manipulated, and its use is applied to those cases in which the part is designed to stand great abuse in service and where maximum production is a prime essential. For such use it has no rival.

Fig. 6. — A connecting rod of malleable cast iron which has been given a 180° twist to illustrate the abuse this product will stand.

While there is no limit to the smallness of the casting that can be made, it is recommended that castings with sections in excess of 2 1/2 inches or over 5 feet long should not be made of this material. In figure 6 can be seen a fairly heavy casting, a connecting rod, that has been given a 180° twist by way of illustrating the abuse this product will successfully withstand.

While some writers intimate that grey iron casting is a competitor, a perusal of the data which follow, in connection with the ultimate strength and elongation of malleable cast iron, will correct this impression. Grey iron that is capable of being machined with anywhere near the facility of malleable cast iron will not exceed about 20 000 lb. per square inch ultimate strength, accompanied by no elongation whatsoever.

The writer is in a position to speak authoritatively in connection with the physical properties of malleable cast iron, its manufacture, the conditions of plant personnel, and the improvements that have taken place in the quality of this product during the past seven years. Not only has the product been improved in ultimate strength and ductility each year during this period, but the plants have been improved both in personnel and metallurgical apparatus, until in the case of the plants referred to little has been left undone in the way of scientific control that would make for uniformity of product.

A certificate, shown in figure 7 is

Fig. 7. — Certificate issued to firms whose products have passed the A. S. T. M. requirements.

issued each quarter to those whose product has passed the A. S. T. M. requirements. This certificate is granted after a daily test of test bars and an examination of the castings at each plant by an inspector attached to the engineer's office of these seventy plants who have co-operated to carry out this and other work of mutual interest. This certificate entitles the recipient to market « Certified Malleable Iron Castings », a product that is guaranteed to equal or exceed material that will stand up to the A. S. T. M. specifications that have just been discussed.

The uses to which these castings are put are many. The railroads, the agricultural implement manufacturers and the automotive industry are all high consumers of these castings, which are manufactured into machines of many types.

During the past three years, the average ultimate strength and elongation of the seventy different plants to which we have referred have been over 53 000 lb. per square inch and 15 % respectively. The last complete monthly record in the writer's possession is that of August of the year 1921. Some individual records during this month which may prove of interest by way of illustrating what some of the certificate holders can accomplish, are given in the following table.

Ultimate strength average, lb. per square inch.	Elongation per cent.
56 393	24.78
56 248	23.91
56 094	24.50
58 906	23.34
54 023	23.44

The average of eight others was 55 120 lb. ultimate strength and 20.27 % elongation. The yield point in these samples averaged about 33 000 lb. per square inch. These results are very remarkable in a metal that can be machined at such high speed.

[625 .143.2]

The « neutral » steel process in rail manufacture,

By Cecil J. ALLEN, A. M. Inst. T.

Fig. 1, p. 482.

(The Railway Engineer.)

In previous issues of the *Railway Engineer*, articles have appeared descriptive of the three principal methods of steel production used in the manufacture of railway rails, and of the respective characteristics and properties under test of the finished product. The two methods obtaining exclusively in this country — Bessemer acid and open-hearth basic — were dealt with in the issues of June, 1920, and May, 1921 (1), respectively; it was shown in those articles that the former, in which no reduction takes place in the phosphorus content of the iron, is dependent for its continuance on supplies of hematite ore, which form a very small minority of the ore deposits available, and is therefore dying out in favour of basic open-hearth working, wherein the dolomite lining of the furnace permits of the reduction of the phosphorus percentage in the iron to a negligible figure, and enables the free use of iron reduced from phosphoric ores in the steel production. In regard to the cost of working, the cheapness of the latter iron, as compared with hematite, tends to balance the greatly increased time of refinement and conversion in the open-hearth process — from 6 to 8 or 10 hours for a cast of 40 to 60 tons in the latter case, as compared with 20 minutes per cast of 12 to 20 tons in Bessemer working. In the matter of production cost, therefore, the Bessemer acid and the open-hearth basic processes are much on the same level, but in regard to the finished product the final superiority probably lies with the latter, in which the systematic reduction of phosphorus to a figure below 0.04 % permits of considerably higher carbon percentages being worked to without risk of brittleness, resulting in a proportionately harder-wearing rail.

In the January 1922, issue of the *Railway Engineer* (1) an article dealt with the basic Bessemer steel process in rail production. In this process are combined the cheapness both of Bessemer working and of phosphoric iron, with the result that basic Bessemer steel is the most

(1) See *Bulletin of the International Railway Association*, September 1921, p. 1334.

(1) See *Bulletin of the International Railway Association*, March 1922, p. 583.

cheaply produced of all the three proces es. But the chief disadvantage of this process lies in the fact that the reduction of phosphorus must be judged entirely by visual indications during the conversion, in the size and colour of the flames at the mouth of the convertor, so that an exceptional degree of expert supervision is necessary if a reliable product is to be obtained. Owing to the bad reputation for unreliability earned by basic Bessemer steel in the past, its manufacture has practically died out in this country, but is, on the other hand, in almost universal use on the Continent of Europe (under the name of the « Thomas » process, after its inventors, Gilchrist and Thomas) for rail production. The article published in the January 1922 issue, which was based on the execution of a contract for basic Bessemer bullhead rails in Luxembourg, sought to prove that it is possible to make a reasonably reliable basic Bessemer steel, in regard to phosphorus content and general test properties, given systematic methods and proper supervision, but did not attempt to place the Bessemer basic process on a par with the Bessemer acid or the open-hearth basic in regard to the wearing ability of the finished rails.

« Neutral » steel production.

At the other end of the scale we have the open-hearth acid process. This is the most reliable of any in that, added to the perfect control of open-hearth working, the process commences, as does the Bessemer acid process, with the purest iron obtainable, but, on the other hand, it is too costly to be applied to rail manufacture. That is to say, the user would obtain little, if any, benefit commensurate with the extra cost as compared with basic open-hearth working. A new complexion has been put on this problem, however, by the process now in course of operation by the Partington Steel & Iron Company, Limited, at their Irlam steelworks, near Manchester. Ordinary open-hearth furnaces are employed, but instead of an acid or basic lining, a « neutral » lining is employed, which is in effect a combination of both. Strictly speaking, no absolutely neutral refractory is known, but it has been discovered that a mixture of dolomite — the usual basic lining — and a certain other mineral, the nature of which it is not desired for the time being to disclose, gives a lining whose reaction is at times weakly acid, and under other conditions of mass action becomes, alternatively, weakly basic. In the furnaces so lined the reaction is up to a certain point oxidising, as in ordinary acid practice, but from then onwards the working is carefully controlled, as in basic practice. In other respects there is nothing abnormal in the « neutral » working, the nature and proportions of the charges of iron, steel scrap (for purposes of dilution), and iron ore (for the supply of oxygen) being all as customary in open-hearth practice.

The main furnace charges at the Partington works are a mixture of hematite and low phosphoric iron, smelted from ores, of which the following are characteristic analyses, in the proportion of about one-half Swedish to roughly one-quarter each of the Spanish hematites :

—	Phosphoric Swedish.	Hematite. Carthagena.	Hematite. San Miguel Rubio Ore.
	Per cent.	Per cent.	Per cent.
Iron	67.00	44.500	53.300
Phosphorus	0.25	0.016	0.007
Manganese	0.10	1.000	0.920

With the aid of the « neutral » lining, the phosphorus is without difficulty reduced to an average percentage below 0.04 %, as in basic working, or even less, but the resultant steel, produced at com-

paratively little above the cost of ordinary basic open-hearth steel, is on a test basis distinctly superior to basic open-hearth steel of the same chemical composition. By the use of such calculations as the Campbell formulæ, to which further reference will be made, it may be proved that this « neutral » steel is, in its test properties, a cross between acid and basic quality.

The figures about to be given are the results of analyses and tests on a rolling of 1 500 tons of 95 lb. British Standard Section bull-head rails recently executed by the Partington Company. The actual section of rail was the original (not the revised) 95 lb. section, and for purposes of composition and tests the steel was regarded as of basic open-hearth quality. For comparison, the British Standard acid and basic high carbon steel composition for rail manufacture are given herewith :

—	Bessemer acid.	Open-hearth acid.	Open-hearth basic.
	Per cent.	Per cent.	Per cent.
Carbon	0.45-0.55	0.50-0.60	0.55-0.65
Silicon	0.10-0.30	0.10-0.30	0.10-0.30
Sulphur, not exceeding	0.06	0.05	0.05
Phosphorus, not exceeding	0.06	0.05	0.04
Manganese, not exceeding	0.90	0.80	0.80

In order that an effective comparison may be made between the results obtained with the neutral process, and those with basic open-hearth and acid Bessemer working under the same specification and with the same rail section, average figures are also given in respect of two basic open-hearth contracts at other works, each for 1 500 tons, and also a 1 000-ton contract for Bessemer acid 95 lb. British Standard rails. It should be added, in regard to the « neutral » rails, that the composition in the first 13 casts was distinctly on the soft side of the specification, and that, from there onwards, for the remaining 28 casts, the carbon content was raised to a higher level. Results obtained from these two separate batches of rails are therefore shown separately.

A comparison of analyses and tests.

Averages analyses throughout each of the five rollings were as follows :

—	Bessemer acid.	Open-hearth basic.		« Neutral ».	
		A.	B.	Part 1	Part 2
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon	0.504	0.599	0.583	0.567	0.592
Silicon	0.116	0.145	0.152	0.155	0.182
Sulphur	0.041	0.038	0.042	0.037	0.039
Phosphorus . . .	0.058	0.036	0.035	0.033	0.032
Manganese . . .	0.793	0.746	0.781	0.775	0.762

Part 1 of the « neutral » contract closely corresponds in average analysis with the second (« B ») basic open-hearth contract, save for a lower average carbon content by 0.016 %, and part 2 shows a closer resemblance to the « A » basic open-hearth average, the neutral steel in the latter case having a somewhat higher average silicon percentage, but there is here a fair and reasonable basis of comparison. The « neutral » rails were rolled from large ingots of 21 by 20 inches square section; an average of 19 passes were given at the cogging rolls, with the usual 5 at the roughing and 4 at the finishing rolls, the finishing temperature being generally between 950 and 1 000° C.

In the « neutral » steel contract, a large number of the falling weight tests were

conducted on top end rail crops, with the manufacturers' concurrence, under clause 6 of the British Standard Specification. The value of such a test to the purchaser is that it is performed on the worst possible condition of the steel in the cast, immediately under the termination of the central pipe in the ingot, where, if cropping of the rolled-out bloom at the cogging rolls has not been fully adequate, piping and segregation may be expected; if a top end crop sustains the test it is reasonable to assume that the remainder of the rails in the cast are free from any suspicion of brittleness. On the other hand, the figures obtained from crop testing are valueless as bases of comparison. Unless the cropping has been exceptionally drastic, there is always a probability of some degree at least of carbon segregate being found in a top end crop, and in addition to this, either extreme end of the bloom, being first through the rolls at each alternate pass, is more exposed to radiation than the remainder, and is therefore inclined to suffer from the effects of cold rolling. It is therefore to be expected that top end crop test-pieces should show greater stiffness under the falling weight test than pieces cut from elsewhere in the rolled-out bloom, and this conclusion is borne out in the results of the tests. A considerable number of check tests were made on pieces cut from ordinary rails, and although in some cases the crop and rail tests were in agreement, in others there were material differences, the crop being invariably harder than the rail, to an extent averaging through-out 0.205 inch in the relative deflections after the second, or 20-foot blow. In order to make the comparison with the previous contracts perfectly fair, all the tests on top end crops are therefore excluded. Average deflections under the falling weight, which was the customary 1-ton tup falling from 7 feet and 20 feet in succession on to a 5-foot piece of rail resting head uppermost on two supports 3 ft. 6 in. apart, were as follows :

—	Bessemer acid.	Open-hearth basic.		« Neutral ».	
		A.	B.	Part 1	Part 2
	Inches.	Inches.	Inches.	Inches.	Inches.
7-foot blow . . .	0.793	0.875	0.925	0 858	0.757
20-foot blow. . .	3.023	3.135	3.280	3.034	2.755

Several of the hardest of the « neutral » test-pieces, of which the deflection after the second blow was only 2 1/2 and 2 9/16 inches, were reversed, and by the agency of a further blow from 20 feet practically straightened out again without fracture — a test of extraordinary severity. It may be added that the maximum deflection permitted in the British Standard Specification is one of 4.1 inches, and this fact serves to illustrate the advances which are being made in hardness even on the new specification recently laid down.

Actual and calculated tensile strength compared.

Tensile tests were conducted in all the contracts on the British Standard test-piece « D », having a turned diameter of 0.798 inch and a cross-sectional area of 0.5 square inch; the piece is turned parallel for not less than 3 3/8 inches, and the extension is measured on 3 inches. With high carbon steel of the quality embodied in the « neutral » casts, the tensile test has a distinctly limited value. The result is influenced adversely by variation in the rate of pulling, by the slightest inaccuracy of alignment of the test-piece in the machine, by the least unevenness in the turning of the test-piece, and in other ways; certain of the hardest « neutral » tests probably suffered slightly in their average exten-

sion by reason of the fact that the hydraulic power for the test machine at this works is taken from a general supply and not from a separate reservoir, with the result that on certain occasions of testing there was a slight up and down « surging » of the beam, probably sufficient to cause the piece to break slightly short of the correct tonnage, and with some deficiency in the percentage of extension. Nevertheless a fine average of results was obtained with the « neutral » steel, which proved itself to be distinctly superior in tensile strength to open-hearth basic steel of the same chemical composition.

In order to reduce the tensile tests on the different contracts as nearly as possible to the same basis of comparison, it is well to apply one of the formulæ, of which many are in existence, relating chemical analysis to breaking strength. In the calculations which follow, the American Campbell formula has been used, differentiating between acid and basic open-hearth working as follows :

Open-hearth acid process :

$$\text{Breaking strength} = \frac{40\,000 - 100\,000\,C - 100\,000\,P - 100\,x\text{M}n}{2\,240}$$

Open-hearth basic process :

$$\text{Breaking strength} = \frac{41\,500 - 77\,000\,C - 100\,000\,P - 100\,y\text{M}n}{2\,240}.$$

The formula has been slightly modified in such a way as to give the result directly in tons per square inch, instead of lb. C, P, and Mn represent the actual percentages of carbon (ascertained by combustion), phosphorus and manganese in the steel by analysis, the values of x and y being in accordance with the following table :

Percentage of carbon.	Value of x (acid steel).	Value of y (basic steel).
0.45	360	270
0.50	400	290
0.55	440	310
0.60	480	330
0.65	520	350

In the case of the « neutral » rails, the nominal tensile strength has been calculated out by both the acid and basic formulæ, and it will be seen that the actual average tensile strength lies between the two calculated figures, whereas in the case of the two basic open-hearth contracts the correspondence between the basic calculation and the actual average is very close. The results were as follows :

CONTRACT.	Ultimate tensile strength. (Tons per square inch.)			Extension in 3 inches. (Average.)
	Actual average.	Calculated as basic.	Calculated as acid	Per cent.
Bessemer acid	49.5	...	...	16.8
Open-hearth basic (A)	51.3	51.7	...	14.6
Open-hearth basic (B)	52.1	51.4	...	12 5
« Neutral » (1st part)	52.0	50.5	60.3	16 0
« Neutral » (2nd part).	54.7	51.1	61.4	13.4

It may be added that, whereas the British Standard Specification limits the tensile tonnage to a maximum of 55 tons per square inch, in these contracts this top limit was removed, the lower limit of 46 tons per square inch (in the case of basic open-hearth steel) only being worked to; above 50 tons per square inch the customary minimum extension of 10 % was required. Not only will it be noted from this table that the « neutral » steel gave a higher average tensile test than the steel in the basic open-hearth contracts, but also, proportionately, a materially better percentage of extension.

Some notable « neutral » casts.

If the records of several individual casts be examined, the claim of the makers that this « neutral » steel is in its capacity for wear fully equal to a mean between acid and basic open-hearth steels of approximately the same chemical composition is well substantiated. Several of the best results are tabulated herewith :

—	Cast					
	No. 1	No. 24	No. 30	No. 31	No. 33	No. 38
Analysis.						
Carbon . . . . Per cent.	0.610	0.607	0.620	0.598	0.585	0.600
Silicon . . . . —	0.159	0.177	0.131	0.187	0.177	0.149
Sulphur . . . . —	0.037	0.046	0.036	0.037	0.040	0.044
Phosphorus . . . . —	0.032	0.033	0.034	0.030	0.030	0.035
Manganese . . . . —	0.780	0.770	0.790	0.760	0.720	0.740
Falling weight test, deflections						
7-foot blow (top crop) . . . . . . Inches.	0.63	0.69	...	0.63	0.81	0.75
20-foot blow (top crop). . . . . . —	2.56	2.50	...	2.50	2.81	2.63
7-foot blow (ordinary rail) . . . . —	0.81	0.75	0.63	0.75	...	0.88
20-foot blow (ordinary rail) . . . . —	2.88	2.75	2.50	2.75	...	2.88
Tensile test.						
Breaking strength (tons per square inch) :						
Actual	55.4	58.2	57.6	55.4	56.0	57.0
Calculated (basic).	52.6	52.3	52.6	51.4	50.4	51.6
Calculated (acid)	63.5	63.1	64.6	62.1	60.4	62.1
Extension in 3 inches . . . per cent.	18.0	9.5	11.0	13.5	17.5	15.0
Reduction of area. . . . . —	25.3	11.7	11.7	18.6	27.4	20.8

It will be noted that the majority of the tensile strengths shown in this table are almost exactly midway between the figures calculated by formula for acid and basic steel respectively. The association of such percentages of extension as 15 with 57.0 tons (cast 38), 17.5 with 56.0 tons (cast 33), and 18 with 55.4 tons (cast 1) is in itself an exceptional tribute to the quality of a steel produced and rolled by ordinary methods, without alloy or special heat treatment of any kind.

There is reproduced herewith a photo-

micrograph, magnified 125 diameters, of the structure of a rail from cast No. 31, from which the close grain and uniform quality of the steel are apparent. An impression test on the same case gave the high Brinell hardness number of 289, and this was by no means the hardest of the casts rolled.

Fig. 1. — Photo-micrograph of « neutral » steel from cast No. 31 magnified 125 diameters.

It is interesting, in conclusion, to recall the enormous strides which have been made in the quality of rail steel during the last decade. During the course of last year, a revision was published of the British Standard Specification for bull-head rails, replacing the previous revision af June 1909. The latter demanded a deflection under the second, or 20-foot blow, at the falling weight test, of from 3 to 4 1/4 inches; under that specification it would have been necessary to reject 34 out of the 41 « neutral » casts rolled, as under 3-inch deflection. When we come to the old British Standard tensile test, of 40 to 48 tons per square inch, we find that every cast but one, which gave a result of 47.6 tons, would have been rejected as coming above the specified limit of 48 tons. Even the new British Standard Specification imposes a top tonnage limit of 55 tons per square inch, but fortunately this had been removed in the specification actually worked to, or one-half of the casts rolled, on which the minimum percentage of 10 % or 3 inches, as a guarantee of ductility, had been more than secured, might still have been thrown out. These considerations would suggest that rigid standardisation is an obstacle to progress unless the standard is frequently reviewed, and if necessary modified, to meet the new conditions constantly arising from enlightened and progressive manufacturing methods.

[621 .133.5]

The mechanical drafting of locomotives,

By Frans H. C. COPPUS.

Figs. 1 to 3, p. 487.

(*Railway Age.*)

Generally speaking, it is a simpler task to incorporate extensive improvements into the design of a new locomotive than to apply them to one already in operation. Though the author would be the last person to discourage the development

of the locomotive along radical lines that would require a total reconstruction or rearrangement of the present locomotive power plant, he believes that more can be accomplished for the immediate future by adding to the existing locomotive equipment which is standard, in principle at least, in stationary and marine practice, and which does not necessitate extensive or costly alterations. The existing locomotives, 68 000 in this country alone, represent such a large investment that no matter how efficient a new locomotive may be built, it is out of the question to relegate them to the scrap heap, and they will be with us for many years to come.

In the treatment of this subject the author has therefore limited himself to the existing locomotive. The supporting data employed are based on modern steam locomotives equipped with superheater and brick arch and fed by means of a live-steam injector.

The use of the exhaust steam for drafting the locomotive makes the locomotive power plant differ in principle from the marine or stationary power plant. In the latter, the boiler is an independent unit, while in the former the boiler and the engine are interdependent inasmuch as the exhaust of the engine creates the draft for the boiler and the shutting down of the engine renders the boiler inoperative. Separate the two by substituting mechanical draft for the exhaust jet and there is no reason why the locomotive power plant cannot be fitted out with the devices which have been responsible for the low cost of power generated in marine and stationary power plants. The problem is one of successful adaptation with reliability and moderate maintenance cost, within the present limitations of clearances and other conditions under which the locomotive must operate.

The logical course of development would be as follows : I mechanical induced draft, II undergrate forced draft, III condensing the exhaust steam, IV pumping the hot water from the tender through a waste-gas heater into the boiler, V operating condensing.

Mechanical induced draft.

About ten years ago extensive experiments with mechanical induced draft were made on the Atchison, Topeka and Santa Fe, but they failed because of the « inability to secure a fan of sufficient capacity to properly handle the volume of gases » within the limitations of clearances.

It is doubtful if a fan without the introduction of an intensifying element can be built to overcome this difficulty. Only recently this new element has been brought out. It takes the form of stationary guide-vanes held in a casing. The current of air leaving the propeller is radially subdivided by the individual vanes and taken up without shock. These guide vanes, which have a curvature increasing in the direction of the rotation of the propeller, concentrate the air current and give it a further acceleration, so that a large part of the pressure is produced and a large part of the end thrust taken up by them. This new fan or blower is very much smaller than a multi-blade centrifugal fan of the same capacity, both of commercial construction. Because of this fact the former can be made applicable to the locomotive and the latter not.

Figure 1 shows the smokebox of a modern locomotive fitted out with a blower in the stack and the exhaust pipe and nozzle displaced by a plain exhaust pipe discharging the exhaust steam into the atmosphere. The guide-vane casing takes the place of the lower part of the stack.

A modification of the fan is necessary in order that it may function properly as an induced-draft blower for locomotives, keeping in mind especially, simplicity of construction, low maintenance cost

and assurance that the bearings are kept cool and well lubricated at all times, as the success of the whole scheme hinges not only on the capability of the blower to create the desired draft in the smokebox, but also to stand up under it. A special design has been prepared in which the fan is driven by high pressure steam acting on a turbine wheel at the periphery of the propeller. The revolving unit has oil cooled bearings and the end thrust is taken up by floating the shaft in oil under pressure.

Saving by reduction of back pressure.

One of the outstanding advantages of the use of an induced-draft fan instead of the exhaust jet for drafting the locomotive is the reduction of the back pressure in the cylinders. Prior to the experiments of the Atchison, Topeka and Santa Fe, a series of indicator cards taken from actual road tests of representative locomotives in various classes of service were prepared showing the initial pressure, mean effective pressure, back pressure, and indicated horsepower, and in addition the added mean effective pressure and indicated horsepower which could be obtained by reducing the back pressure to 4 lb. These showed increases in indicated horsepower ranging from 18 to 30 % for simple locomotives and an average of 53 % for a Mallet compound.

The author understands that since these tests were made, the exhaust nozzles have been opened up considerably so that the back pressures have been greatly reduced. It would be idle to estimate what saving in fuel would result from drafting locomotives mechanically due to reduction in back pressure. However, the field seems broad and the prospects bright for enormous savings along this line.

If the only effect of drafting locomotives mechanically was the elimination of the back pressure on the pistons, this would in itself be sufficient to deserve the keenest interest of those responsible for the economical operation of locomotives, but the subject embraces a great many other questions and vitally affects many features in connection with the economical generation and use of steam. Mechanical drafting gives the locomotive a degree of flexibility which it does not now possess.

The steam pressure may be picked up at will or allowed to drop, regardless of the amount of work the engine is doing.

The flexibility of draft makes it unnecessary to favor the engine at any time. The practice of favoring the engine on hills, often no doubt unavoidable under the present method of drafting, is not only wrong from the point of efficiency but cannot help but result in leaky tubes, increasing maintenance cost, and in shortening the life of the boiler.

The advantages of mechanical induced draft mentioned above largely relate to economy in the use of steam after it is once generated. In addition thereto mechanical draft has a strong bearing directly upon fuel economy and will greatly increase the overall boiler efficiency.

The heat loss due to combustible in cinders, estimated anywhere from 5 to 20 % depending largely on the class of service, is generally classed among the « unavoidable losses ». With a fan the constant flow of air through the fuel bed, while gradually changing in intensity, will not lift or tear the fire, and this loss, therefore, can be practically entirely eliminated.

Undergrate forced draft.

To put the ashpan of a locomotive under pressure might prove impractical for several reasons. To overcome this difficulty the author has constructed a grate with hollow bars taking the air

from a wind box to which forced-draft blower is connected.

The forced-draft blower is of the same general construction as the induced-draft blower. It operates, however, in a horizontal position with no excessive end thrust and handles cold air. Therefore, the special lubrication, end-thrust balancing, and cooling features are unnecessary.

While it is not impossible to operate a forced-draft blower in conjunction with an exhaust jet, it is much simpler and better to connect it up to an induced-draft fan. The speed of the two blowers could be so adjusted — and after once adjusted, maintained — that there would be an atmospheric pressure condition in the combustion chamber, if carried to a nicety. This is very common practice with stationary and marine boilers. With the fire door open there would be no inrush of cold air nor any outward leaking of flames or gases. Such a condition is called « balanced draft ». It can be effected only by the use of a forced-draft blower in conjunction with an induced-draft blower, jet blower, or stack. While in a locomotive boiler there is no boiler setting through which air can filter in, the draft over the fire is so much stronger than in stationary practice and the fire door (on hand-fired coal burners) opened so much oftener, that even greater economies than in stationary practice should result from balanced draft.

With forced draft there is no reason why cheaper grades of fuel could not be utilized, which will not only result in economy in the cost of fuel, but also in the cost of handling and storage of coal.

The air space in the grates may also be very small so that no fuel will be lost in the ashpan, and at the same time the grate will let sufficient air through on account of the air being delivered under pressure.

The forced-draft blower creates sufficient pressure to force the air through the fuel bed, leaving only the drawing of the gases through the boiler tubes to the induced-draft blower, and the latter may, therefore, be smaller or may be run at a lower speed than if used alone. For these various reasons it is easier and more efficient to use a balanced-draft system than merely induced-draft.

Condensing the exhaust steam.

When the locomotive is drafted mechanically all of the exhaust steam is available for whatever use can be made of it. Heretofore a small part of the exhaust steam has been used to heat the feedwater. This practice has been quite common in Europe but has been only recently successfully carried out on this continent and to only a very limited extent, less than one per cent of American locomotives being thus equipped. The exhaust-steam feedwater heaters have been constructed on the principle of imparting to the water the maximum amount of heat with the minimum amount of exhaust steam because the latter was needed to draft the locomotive. With mechanical draft, the more steam used for heating the feedwater the better, as the more water will be saved. Railroad men fully appreciate the economy in time and fuel due to the saving of water, especially in freight service, and incidentally the not negligible economy in boiler repairs in bad-water districts.

Pumping the hot water from the tender through a waste-gas heater into the boiler.

The exhaust steam, or as much of it as can be condensed, may be passed through a condenser on top of the locomotive running all the way back of the tender (see fig. 2). The remainder may be allowed to pass to the air free for the time being. Such an arrangement affords a large cooling surface and the amount of water which can be saved without even

attempting to run the engine condensing will be much larger than the amount saved by merely heating the feedwater by means of an efficient heater. The cooling surface may be made more effective by directing over it a current of air created by the speed of the locomotive with or without the assistance of the undergrate-draft blower. It is a simple matter to encase the condenser, provide it with louvers to catch the air, and connect it to the blower inlet by means of a duct. This would have the additional advantage of reclaiming part of the latent heat of the exhaust and supplying the fuel bed with preheated air. A cooling tower located on the back of the tender would further assist materially in condensing the exhaust.

It needs no explanation that with all the exhaust steam available it will be a simple matter to keep the water in the tender at any temperature desired up to the boiling point. This would convert the tender practically into an open heater. Instead of the injector a boiler-feed pump, preferably of the centrifugal type, installed in duplicate, will feed the water through a waste-gas heater into the boiler. The pumps will be located under the cab of the locomotive, so that there will be a sufficient head of water from the tender. Waste-gas heaters have been so far a distinct failure largely on account of the prerequisite that the heater should not interfere with the draft, because if it does the economy derived from its use would nullified by an increase in back pressure.

The author has constructed a waste-gas heater which can be placed in the front end with slight alterations thereto, and which has a heating surface of over 1 000 square feet. By extending the front end this heating surface could be increased if necessary.

From the point of efficiency, it may be considered that at the present time the water is put in locomotive boilers at an average temperature of 60° F. the year round. If, instead of an injector, a pump is used the exhaust steam and the waste gases — which comprise the two largest items of waste energy in present locomotive operation — can heat the water from 60° to 300°. With an absolute steam pressure of 200 lb. this is an undisputed saving in fuel of a little over 20 %.

Operating condensing.

Mechanical drafting of locomotives makes it possible to run locomotives condensing. It can be accomplished without material change in their construction outside of an enlarged and modified tender. This, however, will come later after the steam consumption of the locomotive has been made as small as possible, which will, in itself, make condensing operation easier.

General arrangement.

Figure 1 shows the induced-draft blower located in the stack. This is naturally the logical first step in the development of an induced-draft system for a locomotive, but a blower in such a position is not readily accessible. Practical considerations led the author to place the blower outside of the smokebox. A diagram showing the general arrangement of exhaust pipe, waste-gas heater, and induced-draft blower is shown in figure 3 and will need no further explanation.

Means are provided whereby the guide-vane casing can be quickly separated from the fan casing, giving access to both the fan and the guide-vane for cleaning. Automatic adjustment is provided for maintaining the proper relation between the pressure at the grate bars caused by the forced-draft blower and the draft at the front end caused by the induced-draft blower. The speed of the fans is controlled to keep the boiler pressure from varying more than 10 lb.

The induced-draft blower not only

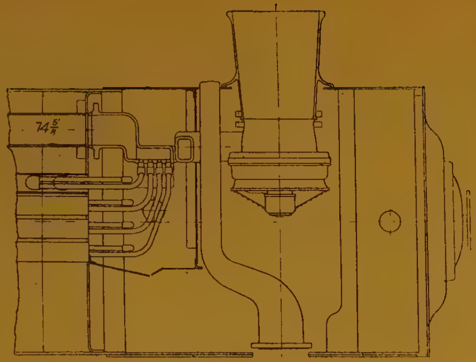


Fig. 1. — Modified form of standard front end with induced draft fan.

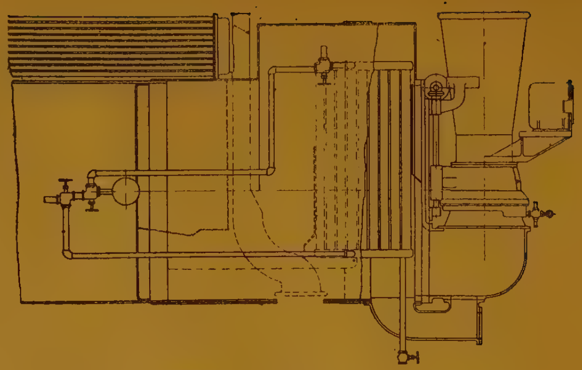


Fig. 3. — Modified front end, equipped with induced draft fan and feed-water heater.

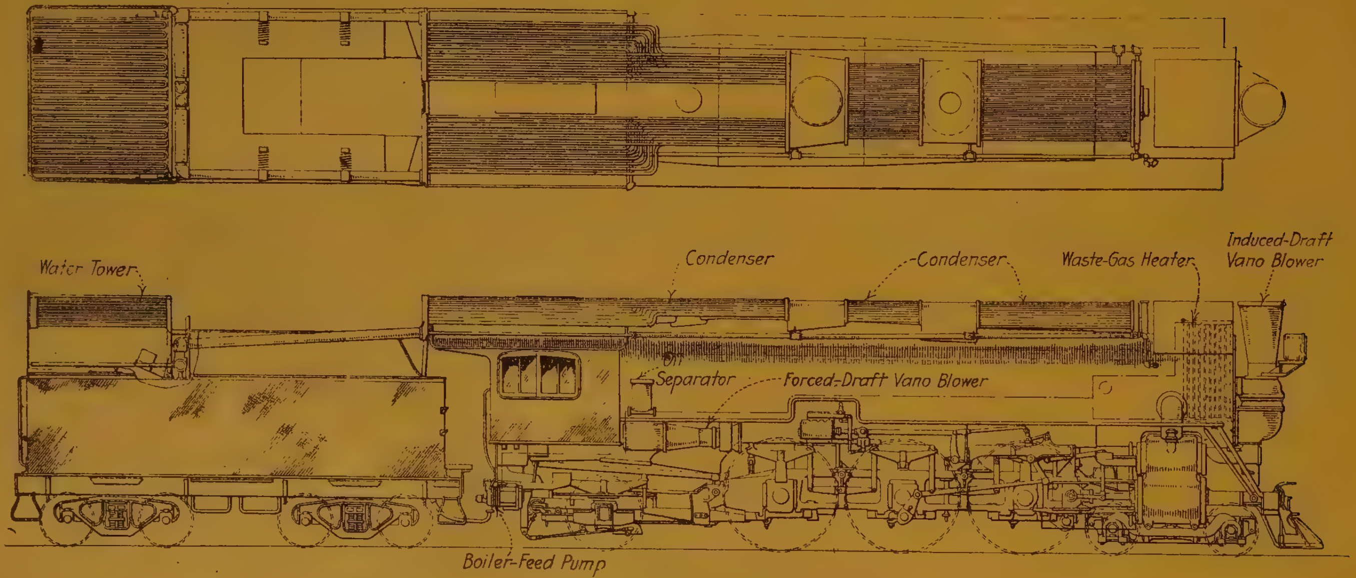


Fig. 2. — Proposed general arrangement of locomotive with induced and forced draft, centrifugal boiler feed pump, and steam condensing apparatus.

furnishes the necessary draft but also controls the amount of fuel used and the water fed into the boiler. Proper provision is made whereby the steam supply to the different apparatus is partly shut off when the engine is standing, or drifting.

Conclusion.

Whatever the saving in fuel will be, due to the elimination of back pressure, the heating of the feedwater, the stopping of the waste of unburned coal through the stack and through the grate, the elimination of cold air over the fire, etc., it is going to reduce just that much the amount of coal that is being fired, or the rate of combustion, which in itself greatly increases the boiler efficiency.

A rate of combustion of 100 lb. shows a boiler efficiency of 65 %. Reducing this rate of combustion to 60 lb., directly and indirectly by means of mechanical drafting, which is not impossible, the corresponding boiler efficiency would be 74.2 %, or a saving of 9.2 %.

In a paper presented by John E. Muhlfeld, at the annual meeting of the American Society of Mechanical Engineers, December 1919, entitled Scientific Development of the Steam Locomotive, the following heat balance is shown as representative of locomotives worked at from 25 to 35 % cut-off and hand-fired:

	Per cent.
Heat absorbed by boiler	55
Heat absorbed by superheater	10
Heat loss in smokebox gases	14
Heat loss in cinders	8
Heat loss in vapors of combustion	4
Heat loss in combustible in ash	3
Heat loss in carbon monoxide	2
Heat loss in radiation and unaccounted for	4
Total.	100

Under the same conditions but with mechanical draft and the waste-gas heater as described by the author, the heat balance should be approximately as follows:

	Per cent.
Heat absorbed by boiler and waste-gas heater	74
Heat absorbed by superheater	10
Heat loss in smokebox gases	5
Heat loss in cinders	2
Heat loss in vapors of combustion	4
Heat loss in combustible in ash	1
Heat loss in radiation and unaccounted for	4
Total.	100

In conclusion, it may be stated that mechanical drafting of locomotives is imperative for the following reasons :

a) It reduces the back pressure to a minimum, effecting a saving in fuel of form 10 to 30 %; or increasing the power of the locomotive in the same degree, especially as speed increases, therefore adding to the hauling capacity or speed of fast freight and passenger engines, producing additional revenue tonnage and also eliminating or lessening the necessity for double-heading;

b) It produces an engine that is free-steaming under the most adverse conditions and with all grades of fuel, decreasing liability of delay and saving time and money now spent in changing nozzle tips and experimenting with them;

c) It keeps the steam pressure constant, regardless of load, saving steam now wasted every time the safety valve pops and making it unnecessary to favor the engine at any time, thereby saving fuel, avoiding unequal stresses in the boiler and resulting in saving in maintenance cost;

d) It increases the efficiency of the boiler and grate by effecting better combustion and eliminating the waste of unburned fuel through the stack and in the ashpan — and incidentally stopping the inrush of cold air every time the fire door is opened — thereby avoiding sudden cooling of crown sheet and tubes;

e) It makes possible the use of cheaper

grades of fuel, resulting in large economies and in simplifying the handling and storage of coal;

f) It eliminates the smoke nuisance in terminals and freight yards;

g) It makes it possible to condense from 25 to 95 % of the exhaust steam, depending upon the season of the year and the kind of condensing apparatus used, resulting in economy in the cost of water and of maintenance;

h) It effects a saving in fuel of 20 % by making it possible to preheat the feedwater from 60 to 300° F., and incidentally greatly decreases the cost of maintenance by eliminating unequal stresses caused at present by the great difference in temperatures between the lower and upper portions of the boiler;

i) It reduces the rate of combustion, thereby increasing the boiler efficiency;

j) It lessens the work of both engineer and fireman, thereby necessarily increasing their efficiency.

[385. (06]

International Union of Railways,

By J. VERDEYEN,

GENERAL SECRETARY
OF THE PERMANENT COMMISSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

On the proposal of its Committee on Transport, the League of Nations, on the 3 May 1922, passed a resolution, article 6, which was drawn up as follows :

« Without prejudice to existing arrangements and so that all possible steps may be taken without delay to re-establish international traffic under conditions as satisfactory as those which existed before the war, the countries represented at Genoa express a desire that the administrations of the French railways will call together as soon as possible a conference of the technical representatives of all the railway administrations of Europe and of other interested countries. This conference will be called together to consider steps to be taken in order :

« 1° That administrations may immediately put into action all steps that are within their power with this object in view;

« 2° That their representatives may agree on matters to be laid before their respective governments which require to be dealt with under government control.

« At this meeting a special point should be the establishment between the administrations interested of a co-operation as close as is possible without sacrificing the independence of the various roads, and *without encroaching on the work of existing international associations.* The technical representatives ought to consider, amongst other points, the creation of a permanent conference of the administrations for the unification and improvement of the arrangements and operation of railways *with a view of international traffic.*

« The first item to be placed on the agenda for the conference should be that of through rates and the diminution of the troubles arising due to variations of exchange which affect international transport. »

Mr. Le Trocquer, Minister of Public Works of the French Republic, instructed the Committee of Control of the main French railways to carry out this resolution, and on the 17 September 1922, this Committee, under the presidency of Mr. Dervillé, called together in Paris a conference of the railway administrations of Europe to which it submitted draft Articles of Association for the organisation of the International Railway Union, having for its objects *the unification and improvement of the conditions of the arrangements and operation of railways, having in view the question of international European traffic.*.

The following countries were represented at this conference :

Germany,	Denmark,
Great Britain,	Spain,
Austria,	Esthonia,
Belgium,	France,
Bulgaria,	Greece,
China,	Holland,
Hungary,	Portugal,
Italy,	Roumania,
Japan,	Sarre,
Lettonia,	Serbia,
Lithuania,	Sweden,
Luxemburg,	Switzerland,
Norway,	Czecho-Slovakia.
Poland,	

China and Japan were invited owing to the administrations operated in Asia being interested in international European traffic.

The League of Nations, as well as Oriental railways, also sent delegates to this conference.

At the opening meeting, the Minister of Public Works of the French Republic, in a remarkable speech, dealt with the problem of international transportation by rail and the numerous difficulties which were taking place in international relations at the present time. He also spoke on the question of customs and police at the frontiers, with the insufficiency of new stations at frontiers and with questions of personnel and finance. Mr. Mange, manager of the Orleans Company, was made President of the new organisation, and Mr. Leverve, chief engineer of the same Company, was appointed general secretary.

A special committee composed of representatives of the following countries : Germany, England, Italy, Switzerland, Belgium, France, Holland, Poland, Roumania and Scandinavia, was elected to examine the draft Articles of Association proposed by the Committee of the main French roads, and to present definite Articles of Association to the General Meeting (A. G.).

This committee, presided over by Mr. Paul, manager of the Midi Railway, and to which Mr. Leverve acted as reporter, presented a suggestion for the Articles of Association, which was adopted almost without modification at the meeting held on the 22 October.

We give below the actual text of the Articles of Association adopted :

Article 1.

Object of the U. I. C.

The U. I. C. has for its object the unification and improvement of conditions of arrangements and operation of railways, having in view international European traffic.

Its headquarters are at Paris.

Article 2.

Administrations to be admitted.

a) The following may be members of the International Railway Union :

1° « Founder » administrations as given in the attached list;

2° Railway administrations which will be afterwards admitted upon application. They must agree to accept the regulations of the U. I. C. and fulfil the following conditions :

To have in operation at least 1 000 km. of road of standard or larger gauge situated in Europe and connected by rail with the lines of the U. I. C.;

Engaged in public traffic, both passenger and goods.

In spite of the above, an administration working a railroad less then 1 000 km. in length, or even a narrow gauge road, may be admitted as a member of the Union if it is felt that it is of sufficient importance for international European traffic.

b) Transportation companies, railways and others which do not fulfil the requested conditions for membership of the U. I. C., but which have relations with lines dealing with international traffic, may be, upon application, admitted as adherent administrations to all or part of the regulations and institutions of the U. I. C.

c) The bye-laws governing the application of admission from administrations, either as members or adherents, are set out in article 8 § *a*.

Article 3.

Administration of the U. I. C.

a) The administration is entrusted to a Board of Management (C. G.) consisting of twelve member-administrations and the administration to which the president belongs.

The headquarters of the C. G. are in Paris.

The General Meeting (A. G.) appoints for ten years the countries or groups of European companies from which the members of the C. G. are to be chosen. In these countries or groups of countries the member-administrations choose from among themselves those who they desire to become members of the C. G. and determines the length of their term of office.

The C. G. appoints from its members a member-administration from which the president shall be elected and three member-administrations from each of which shall be appointed a vice-president.

The C. G. delegates the carrying out of the ordinary business to a committee composed of the president and the three vice-presidents.

A quorum for the Board of Management (C. G.) is formed when at least seven members are present. The decisions of the C. G. and of the committee shall be determined by the votes of the majority of members present; in case of there being an equality of votes, the president shall have the casting vote.

The official language of the U. I. C. is French, but all documents, agreements, regulations, etc., which are of interest to countries speaking German will be translated into German and printed in the two languages, the French text ruling in case of disagreement.

b) The C. G. is to be assisted by commissions appointed to deal with the chief classes of business and which at present shall be as follows :

1° Passenger traffic Commission;

2° Freight traffic Commission;

3° Through traffic rates and charges Commission;

4° Exchange and common use of rolling stock Commission;

5° Technical questions Commission.

The Commissions are appointed by member-administrations of a certain number of countries nominated for five years by the General Meeting (A. G.), on the nomination of the C. G. The president may, for the purpose of dealing with certain subjects, join several commissions together to form a joint commission.

The member-administrations of each country are to be represend on the commission by one or two appointed delegates. Substitutes may be provided for these if necessary. They may be assisted by technical experts who act wholly in an advisory capacity.

The adherent-administrations may take part in the meetings of the commissions in an advisory capacity under the conditions indicated in § *e* below.

In addition to the permanent commissions mentioned above, the Board of Management (C. G.) may appoint temporary commissions for dealing with special subjects.

c) The general secretary is to have charge, in Paris, under the direction of the C. G. of the preparation and carrying out of the business.

The general secretary is to be provided by the French member-administrations, and his staff are to be nominated by the C. G.

The general secretary shall take part in any meetings of the commissions, of the C. G., of the preparation and carrying C. G. in an advisory capacity.

d) The C. G. manages the U. I. C. and acts as its representative in dealing with any third party.

Matters for consideration are brought to its notice by the members.

It distributes the various business amongst the different commissions.

It arranges for and calls together the General Meeting (A. G.) and draws up the agenda for the latter.

e) The commissions make recommendations for the General Meeting (A. G.).

They can, by agreement with the C. G., invite to their meetings administrations, either member or adherent, who they feel will assist them in the examination of certain questions.

They act as arbitrators in cases such as those set out in article 9.

f) The internal regulations of the U. I. C., approved by the General Meeting (A. G.) or special decisions of this latter, lay down what classes of business should be dealt with by the C. G. at the request of the commissions, either final or provisional, subject to ratification by the next General Meeting (A. G.).

g) The C. G. may, if it thinks necessary, send back to a Commission for further consideration, a decision or motion of that Commission informing it of the reasons for such action.

Article 4.

General Meeting.

The General Meeting (A. G.) under ordinary conditions meets every five years.

The C. G. may call an extraordinary session of the General Meeting (A. G.); one may be held at the request of six member-administrations belonging to at least three different countries and representing not less than 10 % of the total votes of the U. I. C.

Article 5.

Method of voting.

a) Only member-administrations are to be represented at the General Meetings (A. G.).

One member-administration may be represented by another, providing that the C. G. be informed of this in advance.

b) The number of votes is determined beforehand by the number of kilometres of line under operation as appears from the table of the member-administrations attached to the Articles of Association. The registration of new lines is made by the C. G. at the request of the member-administration interested, on the condition that the new line is open to public service for both passenger and freight traffic.

A member-administration may, in addition, have registered in its name lines

in the same country to which it belongs which are not parties to the Union, but whose lines are of interest for international traffic and who have given authority to the member-administration to represent them. The kilometric length of these roads will be added to that of the member-administration, which, as far as the said roads are concerned, will be responsible to the U. I. C. in the same way as they are for their own lines.

There will be allotted to the whole of the member-administrations of the same country, after the total length of their lines has been ascertained, the number of votes given in the table attached to the present Articles of Association.

Votes allotted to the member-administrations of one country are divided between them pro rata to the number of votes corresponding to the length of line each of them possesses. In calculating these numbers, they shall be taken to the first place of decimal and divided up so that the total exactly corresponds to those of the country.

c) In case of emergency, and in order to avoid calling an extraordinary meeting, the C. G. may consult the member-administrations by correspondance. A postal vote is not valid if the opposition to any proposal exceeds 10 % of the total votes of the U. I. C.

d) At the sittings of the commissions, the delegates nominated by the member-administrations of each country as laid down by article 3, § *b*, are allowed one vote plus one fifth of the number of votes allotted to the member-administrations of their country by § *b* above; the calculation shall be taken to the first place of a decimal. These votes are divided among them according to the wishes of the member-administrations, and in default of agreement, equally.

e) The section of the League of Nations dealing with communications and work may, if it wishes, send representatives *ad audiendum* to the General Meetings (A. G.).

Article 6.

Giving effect to votes and decisions.

a) The votes at the General Meeting (A. G.) will only be decisive and obligatory in the specific cases set out in the articles and regulations of the U. I. C. and under the following conditions :

1° That the administrations interested obtain the approval of the administrative authorities or government of their country in matters which are or will be ultimately referred to them. If, owing to this, any one of the administrations interested does not agree with the decision, it will not become obligatory on the others. Administrations are bound to make known the views of the government authorities with the least possible delay. Failing a decision being arrived at by these authorities in the time fixed in each case by the C. G., this body advises each of the interested administrations, and in accordance with the arrangements of the last paragraph, the decision arrived at by the General Meeting (A. G.) does not become obligatory;

2° That the decision is not contrary to the provisions of any existing or future agreements between the countries interested.

b) In order to be binding, the votes of the General Meeting (A. G.) ought, moreover, except where provided for in the articles and regulations :

1° To receive at least 80 % of the votes of those present at the meeting;

2° Not to be opposed by 10 % of the total votes of the U. I. C.

In order to be admissible, any objection must be received by the C. G. within five weeks of the notification of the result of the vote. The Board of Management will in each particular instance de-

cide whether more time shall be allowed in the case of Asiatic railways.

At the end of the time allowed for receiving objections, the C. G. re-examines, if necessary, the votes and notifies the definite decision to the member-administrations and also to the adherent-administrations interested.

The administrations interested, within four months, inform the C. G. whether they have given effect to the decision.

The time allowed for raising objection may be, in case of urgency, reduced by special authority of the General Meeting (A. G.).

c) The vote of the General Meeting (A. G.) is immediately effective, without there is opposition, in the following cases :

1° Nomination of countries called upon to furnish members of the Board of Management;

2° Election of commissions;

3° References to the commissions;

4° Place of next meeting.

d) The articles and regulations of the U. I. C. can only be altered by the General Meeting (A. G.), where vote in this case is to be in accordance with § *b* of this article.

e) No traffic charge (rate or conditions) can be enforced against its will on any member or adherent.

f) The rules laid down in §§ *a* and *b* of this article apply to the decisions of the C. G. and of the commissions in cases where the power to decide is conferred on them by the articles and regulations or by special authority from the General Meeting (A. G.).

The time allowed for objection to be raised to the decisions of a commission may, in case of urgency, be reduced by the C. G.

g) In all cases other than those set out in §§ *a* to *e* of the present article, the conclusions of the General Meeting (A. G.), of the C. G. and of the commissions adopted by a majority of votes are in the character of wishes or recommendations to the administrations, members and adherent, who will carry them out where possible.

Article 7.

Division of the expenses of the U. I. C.

a) The contributions of the adherent administrations are fixed by the General Meeting (A. G. on the recommendation of the Board of Management (C. G.).

b) The expenses of the U. I. C., other than those laid down by § *c* of this article, are, after deducting the contributions under § *a*, divided between the member-administrations pro rata to the votes they have at the General Meeting (A. G.).

Contributions will be asked for by the C. G. at the beginning of each half year to meet the expenses estimated for the half year.

c) The regulations of the U. I. C. provide for other arrangements of dividing the expense in certain special classes of expense in particular cases.

Article 8.

Admission of new members.
Relinquishing membership.

a) The admission of members or adherents is provisionally arranged by the C. G., but is subject to confirmation at the next General Meeting (A. G.). The new member has only the right to vote after this confirmation. In case the C. G. refuses admission, the applicant has a right to appeal to the General Meeting (A. G.).

Railways on which the administration has been altered will not be looked upon as new members.

b) An administration, member or

adherent, ceases to belong to the U. I. C. when the C. G. finds that the regulations for admission are no longer satisfied and has notified the administration of this. The latter has for six months the right of appeal to the General Meeting (A. G.), and if this is done, the decision of the C. G. is suspended.

c) A member may be excluded by the General Meeting (A. G.) at the request of the C. G. for failing to put into force an obligatory decision.

d) Any administration going into liquidation or becoming insolvent *ipso facto* ceases to belong to the U. I. C. The same applies to any administration which is two years in arrears with its contributions.

e) Any member or adherent may retire from the U. I. C. on giving six months' notice.

ARTICLE 9.

Arbitration.

Disputes between member-administrations must be settled by arbitration before competent commissions and not in a law court in the cases set out in the regulations of the U. I. C.

Arbitration is optional in all other cases.

The decisions of the arbitration courts are not submitted for ratification to the members of the U. I. C. If either of the parties involved belong to the commission before which the case is brought, they must neither take part in the discussion or in any way influence the decision.

Adherent-administrations are equally bound to the regulations of the present article in accordance with their participation in the U. I. C.

The closing General Meeting (A. G.), held after the meeting of the Board of Management, examined the proposal of this Board which dealt with the constitution of the statutory commissions and decided that they should be constituted as follows :

1° *Passenger traffic.* — Germany, Belgium, Spain, Esthonia, France, Great Britain, Italy, Poland, Portugal, Sweden and Yugo-Slavia;

2° *Freight traffic.* — Germany, Belgium, Denmark, France, Great Britain, Holland, Hungary, Italy, Lithuania, Roumania, Switzerland, Czecho-Slovakia;

3° *Accounts and Rates.* — Germany, Austria, Belgium, France, Great Britain, Holland, Italy, Lettonia, Norway, Roumania;

4° *Exchange of rolling-stock.* — Germany, Belgium, Bulgaria, France, Greece, Hungary, Italy, Poland, Czecho-Slovakia;

5° *Technical questions.* — Germany, Austria, Belgium, France, Hungary, Italy, Roumania, Sweden, Switzerland, Czecho-Slovakia.

Japan and China are not included in the commissions appointed until the reopening of the Trans-Siberian Railway.

The following resolutions were finally adopted :

First resolution. — « The delegates of the undersigned railways taking part in the International Railway Conference at Paris, engage, in the name of their administration, to take part, as founder members, in the new International Union formed in accordance with the Articles of Association adopted by the Conference today. The administrations who were invited to the present Conference, but who were unable to be represented, will be admitted to the Union as founder members if they apply for admission before the 1 December 1922. »

Second resolution. — « They approve of the composition of the Board of Management and the commissions which have been agreed upon and which are given in the list reproduced below. »

Third resolution. — « The International Union comes into being on the 1 December 1922. »

Fourth resolution. — « In order to provide for the early expenses of the Union, the delegates agree, on behalf of their administration, to subscribe, before the 1 December 1922, a sum of 2 000 fr. multiplied by the number of votes they have allotted to them by the Articles of Association. »

* * *

It is certain that the new International Union has a brilliant future before it and that it will render the greatest service in the development of international relations.

It replaces in fact the *Verein deutscher Eisenbahnverwaltungen,* the German Railway Union, which before the war grouped together the administrations of Central Europe and which was so useful to international traffic.

The programme of the new Union is, however, very much wider, as it includes all the countries on the continent.

We wish to offer it our good wishes, and these are all the more cordial because of the eloquent speech with which the President of the Union closed the concluding meeting. He said, « The International Railway Union re-establishes in the world of transport and exchange a bond between countries which the war has not only decimated and impoverished, but has separated materially and morally. » He added « In the same atmosphere in which we have just met without any cloud to trouble us, we have to work together and with a perfect desire for the recovery of a good understanding and for the improvement of international relations. This is then a matter, the importance of which can hardly be exagerated and which ought to have the happiest effect on the work of pacification which is at the present moment the earnest desire of all countries. »

The object of the International Railway Congress Association is that of encouraging the progress of railway work both from a scientific and technical point of view; its work touches at various times all branches of railway activity, construction, operation, administration and legislation. It willingly places at the disposal of the new Union the valuable information which has been collected at its periodic congresses, and will cooperate also in the realisation of the special aim which the U. I. C. has in view.

MISCELLANEOUS INFORMATION

[621 .87 (.494)]

1. — 80 tonnes travelling cranes at the Bellinzona locomotive repair shops of the Swiss Federal Railways.

Figs. 1 to 3, p. 498.

(*Schweizerische Bauzeitung.*)

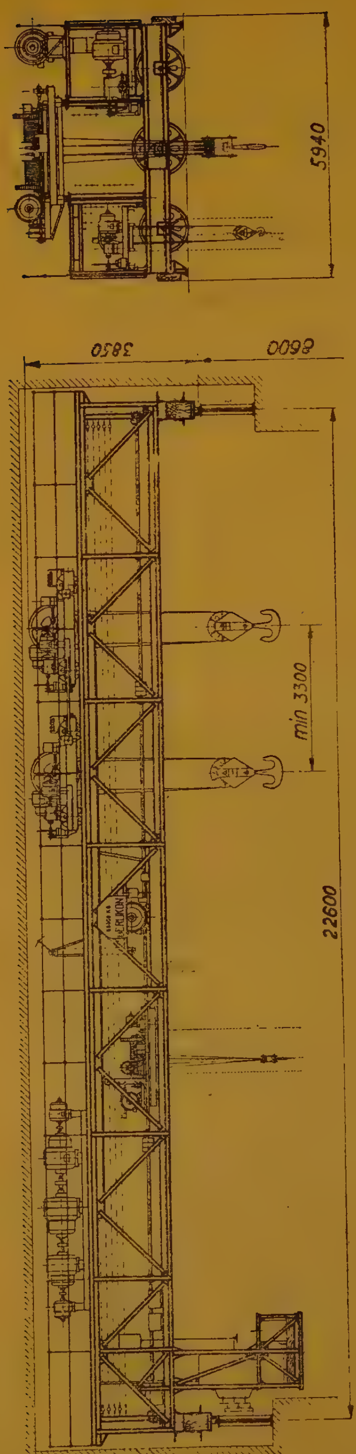
It is necessary that shops for the repair of locomotives should be provided with cranes which permit of the movement of the lifting tackle with extreme accuracy, in order that the erection and dismantling of the smallest parts, as well as of the largest, may be carried out smoothly, both in lifting and lowering. The Bellinzona shops of the Swiss Federal Railways, which are particularly concerned with repairs to the heavy electric locomotives of the Gothard line, are fitted with two 80 t. travelling cranes which fulfil these conditions; we give below a short description of these.

Figures 1 and 2 show the construction of these two cranes which were made at the Oerlikon Machine Works. Each crane has two 40 t. crabs which can be moved independently, the operation being controlled by a « controller » of the Ward-Leonard type, so that not only may the speeds be regulated to a nicety, but they are exactly the same for both crabs. The same system of controller is used for the longitudinal movement of the cranes, thus enabling them to travel together when lifting a locomotive (fig. 3). If a single crab only is required, as for example for moving pieces, the weight of which does not exceed 40 t., it is possible to short circuit the one not in use. For transporting light pieces, a 5 t. auxiliary crab is provided, worked by three-phase current operated by an ordinary controller.

The longitudinal movement of the travelling cranes is operated by 50 H. P. shunt wound continuous current motors. The maximum speed is 246.10 feet per minute with a load of 20 t., and 49.20 feet per minute when fully loaded. The crab is moved by a 4.2 H. P. shunt wound motor; the speed can be varied from 0 to 49.20 feet per minute. For lifting, a 26 H. P. shunt wound motor is provided which works the drums, as is usual, by means of a wire rope and gearing; the lifting speed is 5.91 feet per minute with full load. The auxiliary crab which runs between the girders is provided with an 11 H. P. three-phase motor for lifting (speed 22.97 feet per minute) and 1.8 H. P. three-phase motors for cross traverse (speed 131.24 feet per minute).

The principle of the Ward-Leonard control is sufficiently well known for it to be unnecessary for us to deal with it here. We will only mention that it allows of exact regulation independent of a momentary change in the speed of the motors. The group of the machines which furnish the current for the motors working on this principle will be seen in figure 1 on the left on the top of one of the girders.

The three-phase motor connected to a circuit of 380 volts runs uninterruptedly while the crane is in service. It is coupled to three continuous current dynamos which give a supply to the two lifting motors, the traversing motors for the crabs and the motor which gives longitudinal movement to the crane. The two motors which work them are coupled in parallel. The exciting dynamo is also connected with the circuit which excites all the continuous current machines and assures permanent supply to the electro-magnet of the brake.



Figs. 1 and 2. — 80 t. travelling crane, Bellinzona workshops.

Fig. 3. — Lifting a locomotive weighing 129 t. by means of two 80 t. travelling cranes at the Bellinzona workshops.

[621 .131]

2. — Locomotive failures.

(Engineering.)

In branches of engineering which involve the employment of numbers of relatively small units much, of course, may be done to improve design by the study and classification of failures. The motor car is an example of what may be accomplished in the course of a few years, mainly as a direct result of a study of accumulated facts, to raise the standard of a machine from a level at which it was considered lucky to get it to run at all, to one in which it is now regarded as akin to disgraceful to have a failure. The reliability of the locomotives on our British railways is another case in point, but the evolution has been spread over rather longer years. The careful collation of the causes of failure has led to variations of design, sometimes of themselves of a trivial nature, by which the number of failures has been gradually reduced — that is, of course, failures due to causes amenable to such treatment. There must always be failures due to influences which design cannot affect, such, for instance, as those arising from neglect, or wilful or ignorant misuse. Others arise from circumstances which so far as the locomotive is concerned are more or less fortuitous, such as an exceptional run of poor coal. These have lessons for the purchasing or stores department, rather than for the mechanical staff.

Although a good deal has been done in the collection and sifting of such information on our railways, and the resulting figures have often the recommendation that they run over a period of years, we doubt whether the attempt has ever been made in this country to present such an analysis of failures as that drawn up by Mr. F. C. Pickard of the Delaware, Lackawanna and Western Railroad, and summarised by him in a paper read some little time ago before the Central Railway Club, in the United States. Our conditions, and those of the North American Continent are not to be compared, but as Mr. Pickard's investigation covered the performance of no less than 8 000 engines operating over 25 000 miles of line, the result is interesting, especially as it is representative of conditions of a large part of the Eastern States where maintenance is probably on a somewhat higher scale than in the areas further west. Mr. Pickard's analysis was made not only with the object of putting the finger on weak points of design, but also with a view to stimulating some rivalry between divisions in working for a good record of freedom from failure. By keeping divisions informed of where each stands with regard to reliability, a healthy spirit of emulation can be developed which may be expected to reduce considerably the failures per engine sent out.

In studying the failures a broad classification is first recommended. Mr. Pickard adopted five main classes, among which the failures he scrutinised could be allotted as follows: Hot bearings, 6.71 %; not steaming, 24.19 %; boilers, 11.14 %; machinery, 56.6 %; miscellaneous, 1.36 %. It will be noticed that the bulk of the failures fell to the machinery section, the other causes being relatively small. It is true that the failures due to not steaming were over 24 % of the total, but, as can be shown, many of these so far as the engine's record as a unit goes, are cases more of misfortune than anything else. For instance, no less than 21 % of the « not steaming » cases are put down as directly attributable to inferior coal, and another 10 % to new and incompetent firemen. From these little in the way of engineering lessons can be learned; they are cases pointing rather to the need of improved organisation, which would prevent bad coal getting on to the tenders, and of greater care in the training of the enginemen, in which connection our readers hardly need reminding that the practice in America differs widely from our system of previous lengthy service on cleaning and temporary fireman's duty.

Other groups in the « not-steaming » class

were put down as follows: Superheater units, 8.14 %; stokers, 7.89 %; and cleaning fires, 7.38 %. The last is a type of failure for which operation is responsible, as distinct from the machine, but the other two are due to faulty upkeep or design. In neither case is it stated what proportion of the engines was fitted with these appliances so that the figures are not so interesting as they might have been. Although mechanical stokers have been adopted fairly widely for new power, there are more engines running on which hand firing is used. However, in view of the comparatively recent introduction of reliable models of mechanical stokers the number of failures is by no means discouraging. The service is very severe, and the fact that robust machines have been developed capable of effectively meeting requirements is a high tribute to the ingenuity and perseverance of American designers in attempting to break down previous limiting conditions.

Among the boiler failures, in themselves not a large proportion of the whole — a fact which is a little surprising in view of the bad water often used — the largest number of failures is due to tubes. These represent 26.52 % of the total, and are presumably tubes leaking, etc., for burst tubes are separately given as being responsible for 18.24 % of the total. These two together outweigh other causes of boiler trouble, though grates, which it must be remembered are of the rocking type, are recorded as responsible for 13.81 % of all boiler failures.

Perhaps the most interesting class of failures, at the same time the largest, as already indicated, is that of machinery failures, representing 56.6 % of the whole. These do not include hot bearings, etc., which, as noted above, are in a class alone. Of machinery failures nearly 24.5 % are side rod failures, which Mr. Pickard traces to the failure to keep axle-box wedges properly adjusted. The second class of nearly 11 % of total comprises cylinder head failures, presumably from bad adjustment of the rods, or the presence of water in the cylinders. The third class, representing 8.81 %, covers valve failures, and the fourth (8.27 %) spring hangers. The remaining 28 sections representing each 5 % and less of the total, cover air hose, air pumps, bolts, pins or keys, springs, tyres or flanges, and so on. Eccentric straps and bolts are put down as representing 2.83 % of the machinery failures, while injector failures only amount to 0.98 % of the machinery class.

It is to be noted that in the hot bearing category eccentrics are recorded as being responsible for 9.17 % of the cases of failure. The largest section in this group is that of truck or bogie boxes (nearly 36 % of the whole) while driving boxes and tender boxes give apparently much less trouble. The former are responsible for 21 % and the latter for only 12 % of the total. The difference is difficult to account for unless it be traceable to the treatment by the engine crew. Driving boxes are so vital that they are given constant attention. Tender boxes are easily accessible, and are of a type which is very free from trouble if the packing be well done. On the other hand, bogie boxes are much less accessible, and are rather apt to receive less attention, or if time happens to be a little short, owing to the difficulty of seeing what one is doing, supplies of lubricant may not be given with quite the same care as is devoted to driving boxes. The remaining class of any note in this group is that relating to pin and valve gear failures, constituting 13.76 % of the whole.

An analysis of this kind points to the parts which need most attention in operation, and consideration in design, and often will reveal weak points which a little change of practice may go far to eliminate.

[385 .52 (.42)]

3. — Rates of pay of railway employees in Great Britain.

As is well known the wages of railway employees in Great Britain are fixed in accordance with a sliding scale, based on the variations in the index figure of cost of living published by the Board of Trade (1).

The table 1, published by the *Railway Gazette* on 30 June 1922, enables one to follow the variations in wages up to 1 July 1922 for the various grades of employees. The reduction of 1 sh. for a decline of 5 points in the index figure has been doubled for the time being as the result of an award issued by the National Wages Board last Spring. It will be seen from the table that the latest reduction did not affect certain grades; these grades are those who had already reached the « Standard » or « B » (guaranteed minimum) rate.

From these figures it will be seen that the drivers, firemen and cleaners have already reached their base rates; and other grades of railwaymen will only be affected as a result of a further decline in the cost of living.

TABLE 1.

Date of operation.	Cost of living figure.	Classes of employees concerned.					
		Drivers and firemen.		Cleaners.		Other grades.	
		Increase.	Decrease.	Increase.	Decrease.	Increase.	Decrease.
1920	Per cent.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.
1 April	130	3	...	3	...	1	...
12 April	...	2	...	2	...	2	...
1 July	150	2	...	2	...	2	...
1 October	161	2	...	2	...	2	...
1921							
1 January.	169	1	...	1	...	1	...
1 April	141	...	4	...	4	...	4
1 July	119	...	5	...	5	...	5
1922							
1 January.	99	...	4	...	4 (*)	...	4
1 April	86	...	2 (*)	...	...	...	...
1 July	80	...	...	...	...	...	2

(*) Standard or « B » rate reached.

With respect to staff paid monthly (clerical and supervisory staff, station-masters, etc.) instead of a reduction of 4 sh. per week, for a fall of 10 points, a reduction of £10 per annum is made or any fraction of that sum which may be necessary to absorb the remainder of the « residual bonus » which was

(1) It will be appreciated that this does not apply to the workshop staff. (*English Editor.*)

granted from 1919 on account of the high cost of living.

* * *

The wages problem in the Railway World is a very complex one: this industry, on account of its very special character, being obliged to recruit its staff from the most varied callings.

The *Railway Gazette* for 21 July 1922 gives some interesting information in regard to this subject. Under the heading of wages it divides the staff of the English railways into three main groups:

1° Clerical and supervisory staff; including salaried officials, clerks, station-masters, inspectors, supervisors and controllers;

2° Operating staff; including the whole of the staff engaged in the manipulation of traffic by road or rail, and the staff employed in the maintenance of the permanent way;

3° Workshop staff.

I. — Clerical and supervisory staff.

In this category the first to be noticed are the juniors, whose salaries are fixed in accordance with their age (15 to 17 years) at rates from £35 to £55 per annum.

On attaining the age of 18 the junior passes, provided he satisfactorily fulfils the conditions imposed by the Company, into the adult class at a commencing salary of £80, and year by year his salary is increased until at the age of 31 he reaches £200.

He then passes, if eligible and as positions are vacant through four classes, each having three scales; the fourth class in stages £210, £220 and £230; and the first class in stages £320, £335 and £350. In all cases these salaries are increased by £10 for employees at stations and depots in London — which includes an area within a radius of 10 miles from Charing Cross.

The salaries mentioned, which have been in operation since 1 August 1919, were calculated on the basis of an average increase of 125 % in the cost of living as compared with 1914, and they represent in round figures an increase of 100 % over pre-war salaries. Generally speaking the introduction of these rates absorbed the bonuses which, up to that time, had been paid on account of the cost of living; because the increased cost of living had been taken into account in fixing the new salaries. There were, however, many exceptions, and it was found necessary to continue bonuses to certain classes of employees. As a matter of fact the increases which were granted in the form of bonuses prior to the adoption of the new scales were proportionately much more in the case of the lower paid grades than the higher paid grades (so much so that in many cases the lower paid staff received a bonus in excess of their salary) and on this account the new salaries were, in some cases, much less advantageous.

In order to rectify this state of affairs the « residual bonus » already mentioned was introduced, and this bonus was subject to a rise or fall in accordance with the sliding scale arrangement. In addition thereto, for each increase in salary, a reduction equal to 50 % of such increase was taken off the bonus, so that in the course of time the latter would entirely disappear.

In the case of employees who were not entitled to a « residual bonus », it was agreed to give them a bonus proportional to any further increase in the cost of living whenever the latter exceeded 125 % over the average of 1914, calculated in accordance with the principle of the sliding scale, *viz.:* £5 per annum (or 2 sh. per week) for a variation of 5 points in the index figure.

This latter bonus reached as high as £40 for adults (18 years of age and over), and £20 for juniors under 18 years of age by the time the cost of living had reached its maximum of 169 % over the 1914 figures. Since then the index figure, issued by the Board of Trade, having fallen continuously, the cost of living bonus and the residual bonus have been reduced in a like degree. As will be seen from the table 2 the former has disappeared fairly rapidly.

TABLE 2.

Average increase in the cost of living.		Reduction in bonuses.		
Date.	Per cent.	*Date.*	Staff in receipt of residual bonus.	Staff not in receipt of residual bonus.
			£	£
December 1920	169	April 1921	20	20
March 1921	141	June 1921	25	20
June 1921	115	January 1922	20	...
December 1921	99	April 1922	10	...
March 1922	86	July 1922	10	...
June 1922	80			

The residual bonuses have also ceased to exist for the majority of employees as from 1 July last.

II. — Operating staff.

The principle governing the wages in this group is quite different from that of the preceding group. With but few exceptions two rates are laid down for every grade, *viz.;* the « B » or « Standard » rate, which is a fixed one, and the « A » or « current » rate, which is subject to a sliding scale. In general the change is 1 sh. per week for a variation of 5 points in the cost of living, but for the present it is 2 sh. until such time as the whole of the increases which were given in July 1920 have been wiped out.

The « Standard » or « B » rate represents an increase of approximately 100 % over the average pre-war rates of pay, and constitutes the limit beyond which variations in the cost of living have no effect, and it cannot be altered without mutual agreement between the employees and the Railway Companies.

The « A » or « current » rate represents the pre-war rates of pay, together with all increases which have since been added by way of bonus. As has already been stated the latter is subject to the application of a sliding scale and is reviewed periodically (in March, June, September and December) by the Central Wages Board. This Board makes the necessary adjustments in accordance with the index figure published in the *Labour Gazette* (issued by the Board of Trade) and the new rates remain in force for the three following months. This is a special advantage for those concerned, because even if a reduction in the cost of living took place immediately after the Central Wages Board had given its decision it would have no effect upon the wages until three months later.

The « A » rate includes advances, varying from 2 sh. to 7 sh. 6 d. per week according to grade and locality, given by the National Wages Board in June 1920, and which were not incorporated in the « B » or Standard rate. It was in order to hasten the disappearance of these advances that the Board decided to temporarily double the reduction of wages consequent upon the reduction in the cost of living.

As stated at the beginning of this article, certain classes of employees have already reached the « standard » or « B » rate, which in the case of cleaners coincided with the figures 99, and in the cases of drivers and firemen the figures 86, as published by the Board of Trade. In other cases the «standard » rate will not be reached until such time as the index figure reaches 70, 60 or even 40. These inequalities are due to the fact that increases in pay in the form of war bonus, or cost of living bonus,

were proportionately much higher for the lower paid men than for the higher paid men — which was perhaps both logical and equitable.

III. — Workshop staff.

In consequence of the difficulties in making collective agreements between the companies and their employees no uniform base rates have been instituted for workshop employees.

Some of the Unions wanted « District » rates, whilst other Unions wanted uniform rates for the same grade throughout the country. As both points of view were irreconcilable recourse was had to other methods, and in the majority of cases rates were fixed for each district as the result of local agreements, or an average rate for comparable work in the district was applied. Generally speaking these agreements were of a temporary character, and a distinction is still drawn between the pre-war rate (which remains in existence) and the numerous increases which have been made since that time, either in the form of increases to the rate itself, or in the form of war wage or bonus.

During the war all wage increases granted to employees in Engineering Establishments were extended to Railway Workshops, including the Churchill Award which gave to dayworkers 12 1/2 %, and to pieceworkers 7 1/2 %, on their total earnings. These wages have not been automatically re-adjusted in accordance with the cost of living by the application of a sliding scale, but any alterations which have taken place have been the result of agreements, etc., between the Compagnies and their employees, or by decisions given by the Arbitration Courts.

The following illustrates how the weekly earnings of a wokshop employee were made up at the time the cost of living reached its maximum, *e. g.*, a fitter employed on daywork at current rates of pay:

	s.	d.
Pre-war rate	30	0
Temporary advance (1920)	6	0
War wage or bonus	33	6
Total	69	6
Churchill Award	8	8

Since that time the temporary (1920) advance and the Churchill Award have been taken off, and only the war bonus still remains. The latter has recently been reduced in the Engineering Establishments by 16 sh. 6 d., and as the Railway Workshops had always followed the Engineering Trades in regard to wages, the Railway Companies believed that they were entitled to reduce the wages of their staff by a similar amount.

They had, however, counted without a recent decision of the Industrial Court, which had lately been occupied in determining methods of fixing base rates for workshop employees on Railways. Using this decision as their authority, the Employees' Union rejected the Railway Companies' proposed reductions, and asked the Court for its opinion. The Court gave its decision on 24 August 1922 in favour of the workpeople, and re-affirmed the fundamental difference existing between railway work and other industries — a difference which ought logically to be shown in the rates paid to the employees.

The Court drew attention to the fact that according to the terms of its latest Decision the wages of workshop employees were not to be interfered with until 1 October 1922. The Court laid stress upon the advantage to be derived from having a delay between the announcement of a reduction in rate, and the application of the same, in order that the door to negotiations might not be closed, and they went on to say that the Companies and their staff should meet as soon as possible and discuss the amount of reduction in wages, but that such reduction naturally would not take place until after the 1 October 1922.

The Companies' proposed reduction affects about 120 000 employees; 80 000 of whom belong to the N. U. R., and the remaining 40 000 to 28 other Unions — most of whom are affiliated to the A. E. U. (Amalgamated Engineering Union).

* * *

It should be noted that the decision of the Court, adjourning until 1 October 1922 any reduction in the rates of pay of workshop employees, is itself based upon a previous

decision given by that body at the time it fixed base rates applicable to workshop employees — as mentioned earlier in this article.

Whilst the salaries of the whole of the clerical staff follow the same plan, and a single principle uniformly regulates the wages of the staff engaged in the manipulation of traffic, one cannot find a similar arrangement in regard to the rates of workshop employees.

Seeing that the previous system, or want of system, bred nothing but complication and confusion, and that both the staff and the Companies complained of this state of affairs, the representatives of both sides resolved at the beginning of February 1922 to take the matter before the Industrial Court for a decision.

The Industrial Court gave its Award on 8 July 1922. It is, without doubt, one of the most important, says the *Railway Gazette*, that this organization has ever been called upon to give up to the present.

As will be seen later on, the Court first set about simplifying and unifying the wages question, and they rejected the solutions offered both by the Companies and the Unions.

The Court divided the various towns and depots into five classes (adding a special one for London and its surroundings), and for each of these classes it awarded different scales of pay, varying according to the class of work performed particulars of which will be found later on.

Before anything else, however, a question of principle required settling, and therein lies the principal decision of the Court. The question resolved itself into whether Railway work should be considered as a separate industry, or whether it was comparable with other industries. As will have been seen, the Court rejected the latter solution, and its decision on this point is categoric.

The principal arguments which it invokes in support of its contention are: the national character of railways; the service which it renders to the community; and the absence of competition which characterises their working — even in those cases where it most compares with other branches of industry; for instance, manufacturing workshops, the produce from which the railways absorb themselves, instead of its being thrown upon the market in competition with that of neighbouring industries.

The Court does not deny that a certain relationship might exist between the wages paid to railway employees and the rates of employees in outside establishments in a given neighbourhood, and has itself recognized this, seeing that the new scales of pay which it has set up for the railway shop workers have been fixed after a careful study of the rates paid to employees in other industries in various districts throughout the Kingdom; but it refuses to admit that the wages of railway employees should be dependent upon those of other corporations to such an extent that they might be modelled thereon, and follow their slightest changes.

This declaration is followed by a number of other decisions, the most important of which is, that no change is to be made in the rates of railway employees until 1 October. Another decision decrees that the new rates of pay shall come into force on 1 October; and a third lays stress upon the necessity of standardising as far as possible the rates of employees — a necessity which the Court has kept prominently before it in fixing the rates. A further decision is to the effect that a part of the war wage (7 sh. per week) shall be incorporated in the new base rates. The war wage up to this time had been 33 sh. 6 d., and by reason of this decision it will fall to 26 s. 6 d. per week (1). If the Companies, after 1 October, are able to reduce this amount by 16 sh. 6 d. (as they would have done if the Court had not decreed otherwise) it will only be 10 sh. 0 d. per week

The award of the Court is followed by an appendix in which are set out the new rates of pay for workshop employees, and they come into force on 1 October.

The first schedule gives the classification

(1) Certain railways had previously incorporated the 7 s. in the rate and paid 26 s. 6 d. war bonus. The award standardised this for all companies. (*English Editor*.)

of the towns and depots: these are divided into five classes in accordance with the importance of the locality and the cost of living in the district.

The second schedule fixes the weekly rates of pay of the employees in each of these classes in accordance with their occupations (a reproduction being given below):

TABLE 3.

OCCUPATION.	London.	Other towns.				
		Class 1.	Class 2.	Class 3.	Class 4.	Class 5.
	Shillings	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.
Boilersmiths	56	52	51	50	49	48
Bricklayers :						
Grade 1	50	46	45	44	43	42
— 2	46	42	41	40	39	38
— 3	36-40	36	35	34	33	32
Carpenters :						
Grade 1	50	46	45	44	43	42
— 2	46	42	41	40	39	38
— 3	36-40	36	35	34	33	32
Coppersmiths	52	48	47	46	45	44
Fitters :						
Grade 1	50	46	45	44	43	42
— 2	46	42	41	40	39	38
— 3	42	38	37	36	35	34
Fitters : Running sheds (rate including special differential)	56	52	51	50	49	48
Metal machinists :						
Grade 1	46	42	41	40	39	38
— 2	42	40	38	38	37	36
— 3	38	37	36	35	34	33
— 4	...	...	...	...	...	...
Painters :						
Grade 1	49	45	44	43	42	41
— 2	45	41	40	39	38	37
— 3	41	37	36	35	34	33
— 4	34-38	34	33	32	31	30
Plumbers :						
Grade 1	50	46	45	44	43	42
— 2	46	42	41	40	39	38
— 3	36-40	36	35	34	33	32
Smiths :						
Grade 1	50	46	45	44	43	42
— 2	46	42	41	40	39	38
— 3	42	38	37	36	35	34
Turners	50	46	45	44	43	42
Wheelwrights	49	45	44	43	42	41

[385. (06.111]

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

Meeting of the Executive Committee on 17 February 1923.

The Executive Committee of the Permanent Commission of the International Railway Congress Association met on the 17 February 1923 at the Head Office of the State Railways, Brussels.

There were present : Mr. TONDELIER, president; Messrs. BRUNEEL and COLSON, vice-presidents, and Mr. BEHRENS, member.

The following also attended : Mr. BRAEM, administrative councillor; Mr. VERDEYEN, general secretary; Mr. HOLEMANS, secretary-treasurer; Mr. HABRAN, assistant secretary-treasurer, and Messrs. DESPRETS and MINSART, assistant secretaries.

Apologies were received from Mr. GRIOLET and Sir EVELYN CECIL, members of the Committee, who were unable to be present.

* * *

I. — The Committee adopted finally the list of questions which will be dealt with at the London Congress of 1925. This list is given below.

II. — The following were approved :

1° the accounts dealing with receipts and expenditure from 15 April to 31 December 1922;

2° the estimates for 1923, calculated on the variable portion of the subscription from the administrations belonging to the Association, being the same as that for last year, *viz.*, 35 centimes per kilometre; and 3° the final accounts for receipts and expenditure of the Rome Congress brought up to 31 December 1922.

III. — Mr. Behrens reported the arrangements which are being made in connection with forming a local Organising Committee for the London Congress. It is hoped to announce shortly what has been done definitely in this matter, and it was stated that Mr. A. B. Cane, secretary of the Railway Companies' Association, would be secretary of the Committee.

IV. — The Committee fixed Saturday 14 July 1923 as the date for the next meeting of the Permanent Commission.

The Association now (February 1923) comprises 228 administrations operating 403 850 km. (250 945 miles) of line.

QUESTIONS

FOR DISCUSSION AT THE LONDON SESSION (1925)

WITH

THE NAMES OF THE REPORTERS

1st SECTION : WAY AND WORKS.

I. — Maintenance of the track. Level crossings (public roads).

A) Different methods of maintenance and repair of the track. (By the administration, by contractors, by piece work or premium system. Mechanical appliances, etc.). Comparison from the technical and economical points of view;

B) Dispensing with crossing keepers. Visibility of the trains from the crossing : warning notices and signals, etc.

Reporters :

Great Britain and colonies. — Mr. Coomber (W. H.), divisional engineer (permanent way), London Midland & Scottish Railway; Hunt's Bank, Manchester.

America. — A and B. — Mr. Ray (G. J.), chief engineer, Delaware, Lakawanna & Western Railroad; Hoboken, N. J.

France. — A and B. — Mr. Ruffieux, ingénieur en chef au service central de la voie de la Compagnie des chemins de fer de Paris à Lyon et à la Méditerranée; 3, rue de Lyon, Paris (XIIe).

Other countries. — A. — Mr. Deyl (H.), ingénieur, conseiller ministériel au Ministère des Chemins de fer de l'Etat Tchéco-Slovaque; Prague.

Italy, Spain and Portugal. — B. — Mr. Mendizabal (Domingo), ingénieur en chef de la division du matériel fixe de la Compagnie du chemin de fer de Madrid à Saragosse et à Alicante; 2, Pacifico, Madrid.

Other countries. — B. — Mr. Maas Geesteranus, ingénieur en chef des voies et travaux des Chemins de fer néerlandais; Utrecht.

II. — Breaking of rails. Joints.

A) Initial causes of breaking of rails : means employed to reduce the number of these breakages, as much from the point of view of the method of use as from that of the specification of material employed;

B) Rail joints : most economical and efficient arrangement.

Reporters :

America, Great Britain and colonies. — Mr. Brown (C. J.), chief engineer, London & North Eastern Railway (Great Northern and Great Central sections); King's Cross Station, London, N. 1.

France. — Messrs. Merklen, ingénieur en chef de la voie et des bâtiments des Chemins de fer d'Alsace et de Lorraine, 3, boulevard du Président Wilson, Strasburg, and Cambournac, ingénieur en chef des études, matériel des voies et bâtiments de la Compagnie du chemin de fer du Nord français, 18, rue de Dunkerque, Paris (X^e).

Other countries. — Mr. Willem, ingénieur en chef, directeur d'administration, président de la Commission de réception du matériel de la voie des Chemins de fer de l'Etat belge; 76, rue Belliard, Brussels.

III (1^{st} and 3^{rd} sections jointly). — Shunting yards.

Shunting and marshalling yards for goods trains. Lay-out and organisation.

Reporters :

Great Britain and colonies. — Mr. Nicholls (R. H.), superintendent of the Line, Great Western Railway; Paddington Station, London, W. 2.

America. — Mr. Wagner (Samuel T.), chief engineer, Philadelphia & Reading Railway; Philadelphia, Pa.

France and Belgium. — Messrs. Moutier, sous-chef de l'exploitation de la Compagnie du chemin de fer du Nord français, 18, rue de Dunkerque, Paris (X^e), and Pellarin, ingénieur en chef adjoint de la voie et des travaux de la Compagnie des chemins de fer de l'Est français, 23, rue d'Alsace, Paris (X^e).

Other countries. — Mr. Simon-Thomas (W.), ingénieur, chef de division au service de l'Exploitation des Chemins de fer néerlandais; 9, Frederik Hendrikstraat, Utrecht.

2^{nd} SECTION : LOCOMOTIVES AND ROLLING STOCK.

IV. — Reduction of the cost of traction.

A) Fuel and its combustion :

a) Choice of fuel : coal, mixing of coals, peat, oil fuel, pulverised fuel, mixing of solid and liquid fuels (colloidal fuel);

b) Apparatus for the combustion of solid fuel (rocking-grates, etc.), liquid and pulverised fuels;

c) Mechanical stokers;

d) Smoke consumption. Spark arresters.

B) Lubrication of axleboxes for all rolling stock :

a) Axleboxes. Plain bearings. Roller and ball bearings;

b) Lubricants.

Reporters :

America. — *A and B.* — Mr. EMERSON (Geo. H.), chief of motive power, Baltimore & Ohio Railroad; Baltimore, Md.

Great Britain and colonies. — *A.* — Mr. COLLETT (C. B.), chief mechanical engineer, Great Western Railway; Swindon, Wilts.; *B.* — Sir HENRY FOWLER, deputy chief mechanical engineer, London Midland & Scottish Railway; Derby.

Other countries. — *A.* — Mr. CHENU, ingénieur en chef, inspecteur de direction aux Chemins de fer de l'Etat belge; 21, rue de Louvain, Brussels.

Other countries. — *B.* — Mr. TETE, ingénieur principal de la 2e division du matériel de la Compagnie des chemins de fer de Paris à Lyon et à la Méditerranée; 20, boulevard Diderot, Paris (XIIe).

V. — Electric locomotives.

High speed electric locomotives.

Reporters :

America. — Mr. WALLIS (J. T.), chief of motive power, Pennsylvania Railroad System; Philadelphia, Pa.

Other countries. — Mr. WEISS (M.), ingénieur en chef de la traction des Chemins de fer fédéraux suisses; Berne.

VI (1st AND 2nd SECTIONS JOINTLY). — Locomotive sheds.

Arrangement of locomotive sheds.

Installations :

a) for inspecting engines;

b) for washing out boilers and blowing through the tubes;

c) for lighting up of engines and getting rid of the smoke;

d) for loading fuel on the engines. Mixing fuels. Disposal of ashes;

e) for the recovery of coal and coke from the residues of combustion.

Reporters :

America. — Mr. BELL (R. W.), general superintendent motive power, Illinois Central Railroad; Chicago, Ill.

Great Britain and colonies. — Mr. MAUNSELL (R. E. L.), chief mechanical engineer, Southern Railway (South Eastern & Chatham section); Ashford (Kent).

Other countries. — Mr. JACOMETTI (Jacometto), ingénieur en chef du service du matériel et de la traction des Chemins de fer de l'Etat italien; Florence.

3rd SECTION : WORKING.

VII. — Dispatching or control systems.

Reporters :

America. — Mr. Hutchens (H. E.), general inspector of passenger transportation, Southern Railway System; Washington, D. C.

Great Britain and colonies. — Mr. Follows (J. H.), chief general superintendent, London Midland & Scottish Railway; Derby.

Other countries. — Mr. Epinay (Ed.), ingénieur en chef adjoint au chef de l'exploitation de la Compagnie du chemin de fer de Paris à Orléans; 1, place Valhubert, Paris (XIIIe).

VIII. — Suburban services.

General organisation of suburban services, including tubes, on lines exclusively used as such, or those not used for this purpose only (lay-out of stations and lines, signalling, rolling stock, time-tables, etc.).

Reporters :

America, Great Britain and colonies. — Mr. Blain (H. E.), assistant managing director, and Mr. Cooper (A. R.), chief engineer, Metropolitan District Railway; Electric Railway House, Broadway, Westminster, London, S. W. 1.

Other countries. — Mr. Direz, sous-chef de l'exploitation des Chemins de fer de l'Etat français; 13, rue d'Amsterdam, Paris (VIIIe).

IX (2nd and 3rd sections jointly). — Fixed signals.

Fixed signals. Principles of signalling for lines with dense traffic and for large stations. Form of day and night signals. Signal lights. Automatic block signals.

Reporters :

America. — Mr. Elliott (W. H.), signal engineer, New York Central Railroad; Albany, N. Y.

Great Britain and colonies. — Mr. Thorrowgood (W. J.), signal and telegraph superintendent, Southern Railway (South Western section); Wimbledon Station, London, S. W. 19.

Italy, Belgium and Holland. — Mr. De Benedetti (Carlo), ingénieur en chef du service des travaux des Chemins de fer de l'Etat italien; Rome.

Denmark, Norway and Sweden. — Mr. Hård (T.), ingénieur principal de l'Administration royale des chemins de fer suédois; Stockholm.

Other countries. — Messrs. Pinus, sous-chef de l'exploitation, and Laigle, ingénieur en chef au service central de la voie de la Compagnie des chemins de fer du Midi français; 54, boulevard Haussmann, Paris (IXe).

4th SECTION : GENERAL.

X. — The eight-hour day.

The eight-hour day on the railways.

Reporters :

America, Great Britain and colonies. — Mr. Clower (W.), assistant to general manager (staff and labour), London Midland & Scottish Railway; Euston Station, London, N. W. 1.

Switzerland, Italy, Spain and Portugal. — Mr. Velani (Luigi), chef du service du personnel et des affaires générales des Chemins de fer de l'Etat italien (Direction générale) ; Rome.

Other countries. — Mr. de Ruffi de Pontevès, ingénieur en chef des mines, directeur du contrôle du travail des agents au Ministère des travaux publics de France; 246, boulevard Saint-Germain, Paris (VIIe).

XI. — Statistics.

Development of railway statistics with the special view of economy in operation.

Reporters :

America. — X... (an American).

Other countries. — Mr. Kirkus (A. E.), director of statistics, Ministry of Transport (Great Britain); 7, Whitehall Gardens, London, S. W. 1.

XII (3rd and 4th sections jointly). — Joint stations and lines.

Allocating the cost of joint stations and lines between several railway administrations.

Reporters :

America, Great Britain and colonies. — Mr. Cope (R.), chief accountant, Great Western Railway; Paddington Station, London, W. 2.

France. — Messrs. Collot, ingénieur en chef adjoint de l'exploitation de la Compagnie des chemins de fer de l'Est français, 13, rue d'Alsace, Paris (Xe), and Bruneau, ingénieur en chef du service central de l'exploitation de la Compagnie des chemins de fer du Midi français, 54, boulevard Haussmann, Paris (IXe).

Other countries. — Mr. Lamalle (U.), ingénieur en chef, directeur d'administration aux Chemins de fer de l'Etat belge; 21, rue de Louvain, Brussels.

5th SECTION : LIGHT RAILWAYS AND COLONIAL RAILWAYS.

XIII. — Establishment of light railways.

Methods of establishing light railways or lines for developing new countries. (Laying out, gradients, standard gauge, narrow gauge, etc.)

Reporters :

America, Great Britain and colonies. — Mr. Marriott (H.), assistant to general manager, London Midland & Scottish Railway; Euston Station, London, N. W. 1.

China and Japan. — Mr. Tsang Ou, directeur général adjoint de l'Administration du chemin de fer de Lung-Hai, member of the Congress Permanent Commission; 5, rue de Mogador, Paris.

Other countries. — Mr. Bonneau, ingénieur en chef des ponts et chaussées, ancien inspecteur général des travaux publics de l'Indochine; 6, rue du Boccador, Paris (VIIIe).

XIV. — Concessions for light railways.

Relations between the concessionnaires of light railways and the authorities granting the concession. Economic and financial administration.

Reporters :

All countries. — Mr. Biraghi (Pietro), ingénieur, administrateur délégué du chemin de fer de Corleone-San Carlo, Piazza SS. Apostoli, 49, Rome, and Dr. Lo Balbo (Pietro), directeur de la Compagnie des tramways à vapeur piémontais, Saluzzo.

XV. — Traction for light railways.

A) Special systems of traction for light railways.

B) Rail motor traction.

Reporters :

America, Great Britain and colonies. — X... (an Englishman).

Other countries. — Mr. De Croës, ingénieur en chef, directeur du service de la traction et du matériel de la Société nationale belge des chemins de fer vicinaux; 48, rue Montoyer, Brussels.